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THE JANUARY SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

JANUARY, 1928

IN NIGERIA

By Professor A. S. PEARSE

DUKE UNIVERSITY

In a previous paper[1] the writer discussed the animals of Nigeria somewhat, and in this one proposes to give a brief account of the native tribes, their distribution and customs. Probably most persons look upon Nigeria as a wild country inhabited by savages. This view is proper to only a limited extent. The country is in places uninhabited and wild, but the people, though they are primitive and though some of their customs may appear to a Caucasian terrible and savage, have a folk lore, arts, and traditions which date back hundreds of years.

Disregarding minor tribes, it may be said that four races dominate Nigeria. In the Southwest live the cheerful, friendly Yorubas. These Negroes have well-organized tribal and national governments which are presided over by an Alafin, who is elected by the chiefs. The slaves of the old days came in part from among these people. In the Southeast in the general region east of the great Niger delta are the Ibos—a race which has its life centered about scattered, more or less independent villages and has no central government and no generally accepted system of laws. Most of the North is inhabited by the negroid Hausas, but the Kanuri, who are of Berber extraction, occupy a considerable area in the East. Both these tribes have long been ruled by Fulani emirs, Semities who probably came originally from Egypt, conquered the tribes in Northern Nigeria and mixed with them. Over all the natives a handful of British administrators exercise wise and helpful control.

[1] THE SCIENTIFIC MONTHLY, Vol. 25, pp. 228–239.

A YORUBA FISHING VILLAGE

A FORD

These men are leaving the country as it is, but continually improving it. The natives retain their own customs, laws, and tribal usages, but are able to have increasing opportunities in the way of education, highways, trade, and better standards of living.

Along the coast fishing is an important means of livelihood. The natives of all coastal tribes are skilful in the manufacture and use of cast nets, fish traps and dug-out canoes. They commonly prepare fish for food by boiling or roasting on a spit. On account of diseases carried by tsetse flies there are no large animals in Southern Nigeria. The natives keep goats and sheep, and also commonly supplement their larders with rats, mice, squirrels, land snails, crabs and shrimps. Cassava is the staple carbohydrate food.

USING A CAST NET

A NATIVE PATH

A variety of fruits are raised but are not commonly eaten by natives.

The rivers are important highways. Rafts of timber are floated down to the coast. Trading canoes are sailed and poled along the extensive coastal lagoons and up and down the rivers. The Nupe tribe handles most of the native transportation on the Niger. On land there are automobile roads connecting the large cities and trade centers, but most of the natives walk over well-kept footpaths and carry their burdens on their heads. In the North donkeys, horses,

PATH LEADING TO A VILLAGE. NOTE THE DRINKING POTS FOR DEVILS ON THE RIGHT

bullocks and camels are commonly used as beasts of burden. On the roads ply Fords, Reo jitneys and smaller numbers of several types of European cars.

Though the workmanship is often crude, the natives are skilful artisans. For centuries the Negroes on the Bauchi Plateau have smelted iron and the smiths have worked it into swords, hoes, axes and other articles. At Bida there are organized guilds which do excellent work in wood, textiles, brass and other metals. Benin was formerly famous for

YARN DRYING

cast images, statues, and *bas reliefs* in metals and wood. Some very worthy work is still done there. In Kano and other northern cities, beautiful leather work is manufactured—pillows, bags, saddles, scabbards, shoes and other objects.

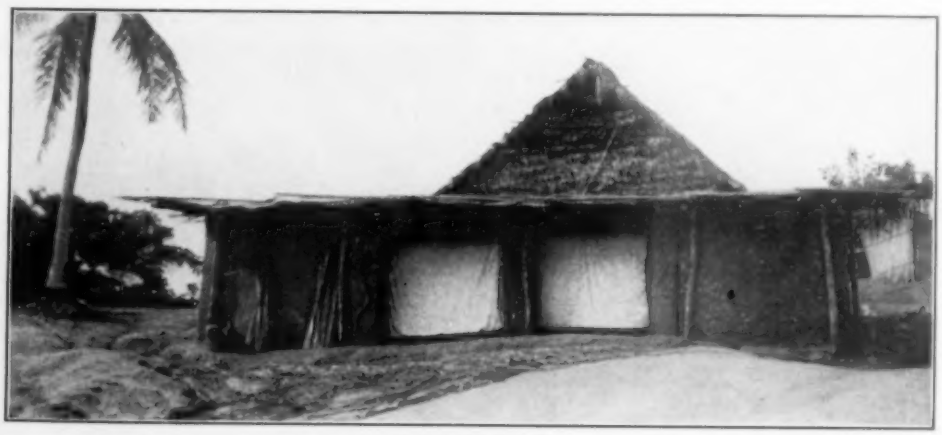
Land tenure is peculiar in Nigeria. The government owns all the land, which is assigned to kings, and these in turn allot it to sub-chiefs, headmen of villages, and finally to private citizens. The plough is not used in Nigeria. In the North the soil is too hard before planting time and in the South the presence of the tsetse fly diseases precludes the possibility of keeping large animals. All the fields are broken up by hand with hoes and mattocks. Among the natural resources of Nigeria the palms take first rank. The most valuable species do not extend far inland. They furnish oil, nuts, wine, fibers, building materials and poles for propelling canoes.

The houses throughout Nigeria are of mud. In the South they are mostly rectangular with thatched roofs, but along the Niger and northward they are commonly round. In the cities of the North, Arab architecture prevails and flat-topped, box-like houses are common. The exteriors and interiors of many of these are beautiful. The roofs are often supported by ornate pillars and arches. In making a Nigerian house the usual procedure is to plaster a framework of poles and twigs with clay. The wooden parts are commonly attacked by termites, which may work in the walls and roof of a house for years. Houses usually contain little furniture. Cook-

A REST HOUSE. THERE ARE NO HOTELS AFTER ONE LEAVES THE COAST OF NIGERIA

ing is done over an open fire or on a pottery stove—in a kitchen, under a porch, or in the yard. There are usually only a few chairs or stools in a village and those who entertain distinguished guests borrow from the headman. The natives commonly sleep on the bare floor or on a rush mat, but a few have bamboo couches. During meals a family usually squats about two or three dishes on the floor and fingers are the only tools used. Most of the Nigerian natives are very cleanly. The yards about the houses and paths are swept by the women or children every day, and where water is available daily baths are usual.

There are some very interesting cities in Nigeria. Lagos (100,000) is the chief seaport. It is a curious mixture of the primitive and specialized; frankly stolid native and cultured European. On the streets there are Mohammedans in turbans and long gowns, naked children, natives clad only in a piece of Manchester cloth or in frock suits, soldiers, police, sailors, goats, chickens, flocks of



A PAGAN TEMPLE

THE IDOLS IN THE TEMPLE AT IBADAN

turkeys and other animals. Half naked carriers with great burdens on their heads mingle with primitive carts, modern trucks and passenger automobiles. A modern drugstore stands near a pagan temple containing wooden idols, and along the street a little way is a mosque. There are many ju-ju shops where all sorts of charms are sold. Lagos is nevertheless a modern city with traffic police, running water and electric lights.

Ibadan (250,000) is the largest native city in Africa. It is in the guinea-grass country and consists almost wholly of mud-thatched houses. There are large, well-regulated produce markets where

THE SACRED CROCODILE AT IBADAN

A JU-JU SHOP IN LAGOS

most of the natives buy their supplies. There is a great pagan temple where gigantic wooden idols stand in solemn rows. In there a wily priest sells ju-jus. These pretty well cover all fields of human desires. A man can buy a charm to assure love, children, death of an enemy, escape after committing robbery (a very high priced ju-ju, but said to be very potent), etc. Perhaps the most unique sight in Ibadan is the sacred crocodile—a great bloated creature which lives in affluence within a mud wall. It is said that his saurian highness was, until the British stopped the practice a few years since, fed on babies. The natives believed that if one of a pair of twins was thus consumed, its surviving mate was assured of greatness, wealth and happiness, and that more or less of this success would spread to all the relatives of the eaten one. Perhaps the twin-feeding is still carried on secretly at times, but the crocodile is

A NATIVE CHIEF WITH HIS FAVORITE WIVES AND MEMBERS OF HIS COURT

now obliged to subsist largely on living chickens, which his priest keeps on hand and condescends to dispose of to the general public for a consideration.

At Ife the six sons of the great god, Enferme, are believed to have descended from heaven and founded the six tribes of the Yoruba Nation. There is a cult of priests who observe ancient rites and have a considerable equipment of very ancient idols. A great polished monolith is said to be the tip of the staff of the warrior god, Oranyan, who left the earth in disgust and returned to heaven.

Empire set its face against slavery in 1807; and in 1852 negotiated a treaty which abolished the shipping of slaves from Lagos.

Of all the cities in Nigeria, Kano is most interesting and picturesque. A wall that is twelve miles long and forty feet thick surrounds the old city. The houses are largely of Arabian style. The camel caravans from all West Africa center at Kano. Two flat-topped bluffs and a great mosque overlook the city.

The natives of Nigeria are remarkable for their courtesy. This is true of their

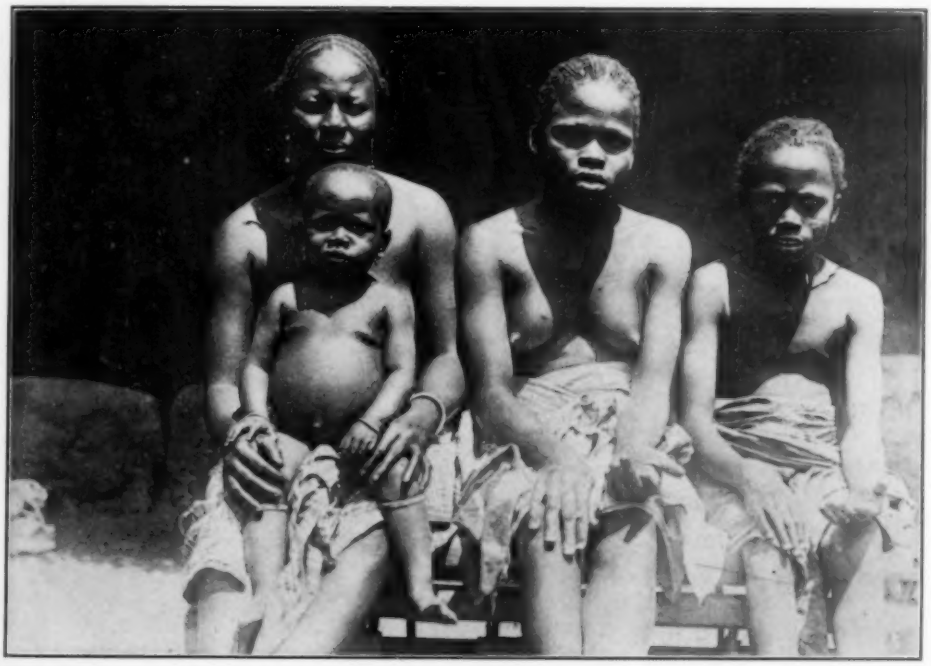
ENTRANCE TO A WALLED YORUBA VILLAGE

Oyo is the home of the Alafin of all the Yorubas, the greatest king in Nigeria. In order to keep up his dignity, he maintains a harem of something over seven hundred wives, which are housed with other members of his court in a "palace." Associated with the court are a number of eunuchs and other slaves. In Nigeria there are no longer caravans of slaves chained together and driven about for sale as in the old days, but a man may, to liquidate his debts, privately sell himself or his children into slavery, or children may be kidnapped and surreptitiously sold. The British

relations among themselves as well as of those with strangers. They have formal and often elaborate social procedures. Two natives meeting on a lonely trail as they pass ask a number of customary questions concerning the welfare of wife, house, children, finances, crops and other rather personal matters which would not be mentioned in polite society by white men. A man who meets his old mother falls on his face; one who meets his cousin bends one knee. A fellow who meets a king falls on his face, throws dust on his head, then creeps forward and repeats the performance three times.

—Photo by V. Galasounof

A WEAVER



YORUBA WOMEN

He is expected to remain flat on his belly throughout his audience and back away, bowing, when he leaves.

The African natives are fond of games and amusements. Iu is a game which is quite widely distributed in Africa. It is played by two or more persons who move seeds from hole to hole in what looks like a wooden muffin pan, or, if better equipment is lacking, play by moving stones about in holes in the ground. Another sport is sort of a masquerade. A few young fellows in a village put on costumes and suddenly appear in the public square of some neighboring village, where they go through more or less farcical or allegorical mummeries. Some mummers are rather professionals and travel about the country from one festival to another. It is important that the identity of the maskers remain unknown and they therefore go completely covered, with gloves and leggins. In the North the Hausas and Fulanis keep some fine

A YORUBA MAN AND WOMAN IN THEIR BEST CLOTHES

—Photo by V. Galasounof

MAKING A FISH TRAP

horses and are very fond of racing. Cock fighting is also a popular sport.

Though there are several types of native instruments, even including primitive violins, most of the music is furnished by drums. The West African drums are elongated and the strings around the sides are so arranged that the drummer may tighten or relax them as he plays. The drums not only make rhythmical music for dances but are also used to imitate the sounds of the human voice. The largest drums can "telegraph" messages for many miles.

Women in Nigeria always hold subordinate positions and spend most of their time working at rather arduous household duties. They gather crops, crack palm nuts, carry water, wash, make meal, and take products to market and sell them. The men do the more

dangerous and difficult tasks, such as fishing, hunting, hoeing and climbing palm trees. A man when he marries, always buys his wife—for from $100 to $300. A wealthy fellow has few ways of showing his affluence and usually buys a number of wives. The ambition of a middle class man is to be able to buy two or three wives, who will largely support him by their labor and thus permit him to live a life of ease.

The Hausa traders travel singly or in small groups throughout West Africa. They walk hundreds of miles each year, carrying their packs on their heads. They are usually armed with a sword, spear, or some other weapon. Squatting in the door-yard they display leather work from Kano, brass from Bida, images from Benin, marabou stork feathers from the Sudan, carved ivory

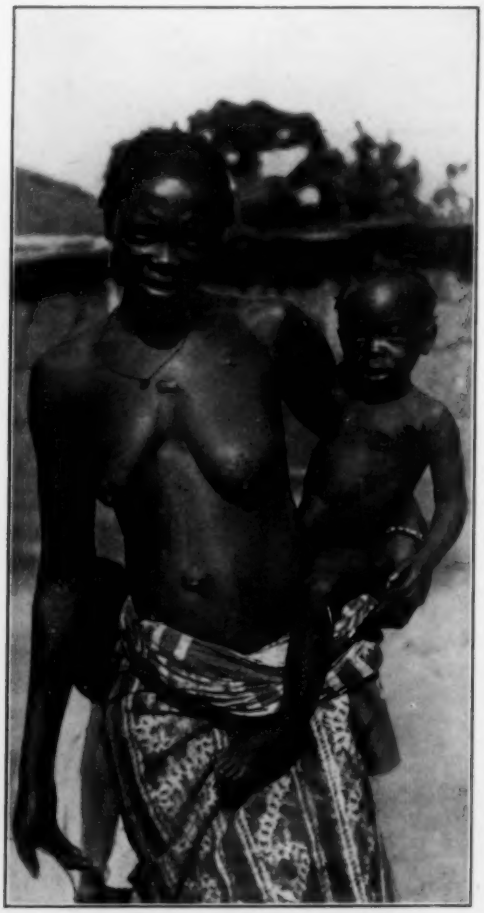
A VILLAGE MEDICINE POT

A FARMER BESIDE A BEAN POD WHICH IS PLACED AT THE EDGE OF A FIELD TO KEEP AWAY THIEVES

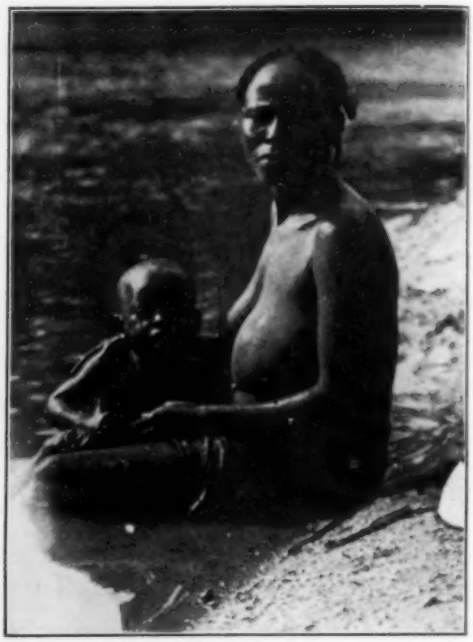
from Calabar, horns and skins from the game country, and other treasures. They tell monstrous and not very artful lies about their wares. They have endless patience and you finally buy in spite of yourself.

In Nigeria belief in devils, fetiches and charms is nearly universal. Most native men have from one to half a dozen leather covered charms tied to their belts. At each fork of a native trail a pot of water is kept, and perhaps also some food is scattered about. Often these offerings are set on a little mound in a cleared and swept space and at times ever covered by a roof, or devil

house. The pot enables the devils to drink as they wander about at night, and they are thus less likely to visit the neighboring villages. Farmers commonly place large bean pods around their fields at the tops of sticks. These are believed to work evil to any one who steals from such a field. One day I walked along a trail with my boy, Rufus, who could read and write in an illiterate fashion and spoke fairly good English. I saw a fallen palm with a hole in its butt and asked Rufus what lived in it, supposing he would give me



MOTHER AND A CHILD WITH AN UMBILICAL HERNIA, WHICH IS QUITE COMMON



THE PUBLIC BATH

the name of some animal, but he answered:

> Devil, Sar.
> What kind of a devil?
> Many devils, veree small. He come at night. No hurt nothing.

During my months in Nigeria, I learned much of the habits and tastes of devils. The natives speak of them as natural concomitants of daily life.

Nigeria, especially near the coast, is probably as unhealthy as any country in the world. Plague is endemic for a hundred miles inland; yellow fever is sporadic but perennial; malaria is common and often followed by blackwater fever; several species of filarial worms live in man; sleeping sickness is inoculated into people by tsetse flies; relapsing fever is spread by ticks and lice. Besides diseases, there are numerous biting flies, ticks, fleas and other small vermin. The female chigger flea has a habit of burrowing under a man's toenail where,

A DEVIL HOUSE

WALL ABOUT A YORUBA VILLAGE

after a time, she grows to the size of a pea and produces a brood of eggs.

Nigeria is a fine example of a pioneer country with rich potential resources. When the diseases are controlled or eradicated it will still be a place for short tours by white men, for the climate is trying. At present the primitive peoples are largely unspoiled by contact with commerce and civilization and offer good material for scientific study. The British are exercising a very wise colonial policy—the traditions, laws and customs being changed only when they seriously interfere with the progress of the country.

A DUG-OUT CANOE OFF SIERRA LEONE

WILD LIFE IN LOUISIANA[1]

By PERCY VIOSCA, JR.

STATE BIOLOGIST OF LOUISIANA

THE mere mention of natural history in connection with Louisiana is suggestive of something different, something primitive, of a wild life varied and unique in a region of jungle land and dismal swamp almost impenetrable. It calls forth thoughts of the mighty Mississippi depositing almost unhindered in its great delta the most fertile soil taken from two thirds of the area of the United States, and thereby giving birth to marshlands of vast extent, followed later, as more sediments are deposited, by cypress forests, which in turn give way to hardwood glades as their level rises higher above the sea.

Of the wooded wet lands there are over two million acres; in these wet lands the shallow waters are protected from the rays of the sun by the dense foliage of the towering cypress and tupelo gums, which have their branches festooned with Spanish moss.

Forming a network through the swamps and serving as their natural drainage channels are deep winding bayous, some cypress bordered, some paralleled by low-lying ridges of land. The ridges, which at most are only a few

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and broadcasted from Station WRC, Washington.

BARATARIA BAYOU

BORDER OF CYPRESS, WITH A HARDWOOD GLADE IN THE BACKGROUND.

A TYPICAL COASTAL PLAIN MARSH

SEVEN MILES SOUTHEAST OF SLIDELL, LA.; HABITAT OF *Rana grylio* (IN THE OPEN LAGOONS) AND *R. sphenocephala* (ON THE EDGES).

A MIXED SWAMP

IN THE PEARL RIVER VALLEY, NEAR THE MOUTH OF BOGALUSA CREEK.

GRYLIO POND

IN THE PEARL RIVER VALLEY; A LAGOON IN A SWAMP—THE ORIGIN OF A GREAT FROG CHORUS.

feet above sea-level, are dominated by gigantic live-oaks, which also are beautifully draped with the gray swaying mosses. Impenetrable cane-brakes and dense thickets of dwarf palmetto make up the dominant undergrowth.

Sections of the former Gulf of Mexico now almost surrounded but not yet completely filled in by the sediment from the river form the tide-level fresh-water lakes of this interesting region.

A total of ten million acres, or approximately one third the total area of the state, is included in this tide-level swamp, marsh and lake region of Louisiana. It is here that we find the richest wild life in the state, if not, indeed, in the entire country. Rich both in number of different kinds and in number of individuals, water-living and woodland forms of animals and plants are freely intermingled.

It is here that we find the last stand of the American alligator, which is at home alike in the marshes, swamps, lakes or bayous. We may see them basking on a shelf along the shore of some lagoon or bayou in the winter or spring sunshine. They retire to their subaquatic tunnels only during cold weather. During the remainder of the year they are difficult to observe by daylight; but after dark their fiery red eyes shine brilliantly by reflection from an acetylene light worn on the head, appearing as balls of fire in the inky blackness.

The alligator is unique among the American reptiles in regard to its breeding habits. The female builds a nest of rushes, sticks and decaying vegetation mixed with humus, and in this places her eggs, which number about sixty. The heat from the sun and the heat given off by the decaying vegetable matter incubate the eggs, which hatch in August and September. The baby alligators, which are about seven inches long, are assisted by the mother in escaping from

EDGE OF A TUPELO SWAMP
WITH BLUE FLAG (*Iris*) IN THE FOREGROUND.

the nest and are carefully guarded by her for about three and a half years, most of them wandering away during the fourth spring, when they average about four feet in length. There are, therefore, from three to four generations of young alligators living more or less amicably together and having their home in their mother's burrow. Although the mother alligator will fight to protect her young, which is not the case with any other kind of American reptile, statistics show that there is far less danger in hunting baby alligators than in being an ordinary pedestrian.

Another monster of this region which is partial to the fresh-water lakes and bayous is the so-called alligator snapping turtle, which weighs upwards of 150 pounds. Unlike the common snapper it is a docile creature. It seems to attract fish into its razor-like jaws by wiggling a worm-like lure on the end of its tongue. The smaller, though actually more formidable, common snapping turtle shows a preference for the shallower waters of the swamps and marshes.

Other kinds of fresh-water turtles are also seen in great abundance, and the water-moccasin and a host of water snakes are ever present.

After a visit to the lowlands of Louisiana you can never forget the tremendous chorus of the male amphibians, the frogs and toads. Of the twenty-four kinds of frogs and toads found in the state not less than eighteen are found in or near the swamps and marshes, and some of these greet you at all seasons of the year. Three kinds are at their best during the height of winter, depositing their eggs even before Santa Claus' annual visit.

Represented in the nocturnal chorus of the amphibians are various imitations of trumpets and other holiday noise-making devices, electric buzzers, sounds

TRANSITION FROM MARSH TO FOREST LAND

HARDWOOD GLADE ON THE RIGHT AND PINES IN THE BACKGROUND.

like the static on your loud speaker, ropes drawn through pulleys, lost chickens, distant cow-bells, sleigh-bells, machine hammers, whistling notes, resembling those of the red-bellied woodpecker, and other noises recalling the sounds of barking dogs, ducks, gallinules, banjos and ukeleles. The southern bullfrog of the open lakes and lagoons sounds like a herd of swine, while the giant bullfrog, the bandmaster *par excellence* and the leader of the chorus, sometimes thousands of individuals together, sounds like so many bellowing bulls.

We must not neglect the smaller creatures of the swamps. Chief among these is the southern red crawfish, the chief food of the bullfrog, the amphibious congo eel and of most of the fresh-water game fishes of the bayous of the region. The red crawfish of the Louisiana swamps is considered by some epicures as the greatest of all known delicacies, in comparison with which the famous Atlantic lobster appears quite tasteless.

For those who crave excitement there is plenty here. The tangled undergrowth of the cane-brakes is the refuge of the Louisiana black bear, the bob-cat, the white-tailed deer and a gigantic race of the timber rattlesnake. More conspicuous, though less forbidding, are the live-oak snake, which is a race of the chicken snake, the American chameleons, the blue-tailed skinks or lizards, the gray squirrel, the raccoon and the opossum, and the cardinal and a host of other small birds.

In the marshes of the state, which were formerly considered as waste lands, we have our most valuable wild life areas. Foremost among the fur-bearing animals is the muskrat, which produces some five million dollars' worth of raw pelts annually. Mink and otter are also

AN ALLUVIAL RIDGE

TRAVERSING A SWAMP IN ST. JAMES PARISH, LA.; HABITAT OF BLACK BEAR AND DEER.

plentiful. The marsh hare is in evidence everywhere and is a most important source of food and recreation. Ducks of many kinds are abundant in the numerous lagoons which dot the marshes, while geese abound on the exposed flats and beaches of the coastal islands.

As we go toward the coast, or away from the mouths of the great rivers, it is interesting to observe how the fresh-water life is gradually replaced by that of the salt-water. The salt marsh-water snake replaces the fresh-water snakes, while the valuable and justly famous diamond-backed terrapin replaces the fresh-water turtles. The southern leopard frog and the southern bullfrog can tolerate a limited amount of salt, but as soon as the salt becomes noticeable, crabs, fiddler crabs and salt-water mollusks take the place of the fresh-water life.

A similar transition takes place in the strictly aquatic animals of the tide-level lakes as we approach the sea. Fresh-water shrimps, fish and mollusks and certain brackish water kinds are at first found side by side, but near the sea-coast fresh-water types give way entirely to marine life, and we find ideal conditions for the growth of the oyster, the blue crab, the large edible shrimp, the menhaden and a long list of food fishes.

In speaking of our marshes, we should point out that their greatest value is as sources of food supply for the great variety of valuable creatures that live in the bays and lakes near the coast. The tons of soil, rich in nitrogen, which are annually deposited in our marshes by the rivers, support a luxuriant growth of rushes, grasses, sedges, reeds and cat-tails as well as of under-water plants. These not only serve as a basic food for

DWARF PALMETTO AND CANE BRAKE
GENTILLY RIDGE, TEN MILES EAST-NORTHEAST OF NEW ORLEANS, LA.

the birds and mammals, but also for the small shellfish, crustaceans and worms which, at the falling tide overflowing into the deeper waters, serve in turn as food for the fishes. The bits of vegetable matter which are washed into the lakes form the direct source of food for our valuable salt-water shrimp, the Louisiana coast producing more edible shrimp than all the rest of the United States together. Again, the food of the oyster is developed largely in the marshes, the receding tidal waters carrying seaward over the oyster beds vast quantities of those minute plants from which they derive their sustenance.

Strange as it may seem, the swamp and lowland region of southern Louisiana is entirely free from malaria, and our permanent wooded swamps are free from mosquitoes.

The seacoast life of Louisiana is varied and interesting. It differs materially from that of the other coastal states owing to the absence of coarse sand or hard rock bottoms and to the presence of soft muds and clays deposited by the rivers. The water is never absolutely clear, for fine sand and silt are always present in suspension. Seaweeds and animals which attach themselves find it difficult to obtain a foothold. Starfishes, sea-urchins, lobsters and rockweeds are absent. On the other hand, creatures that burrow in the sand or mud are abundant, and we have a great variety of worms, shellfish and crustaceans.

MIXED FOREST

OF PINE AND HARDWOODS ON THE PINE FLATS NEAR PEARL RIVER, LA.

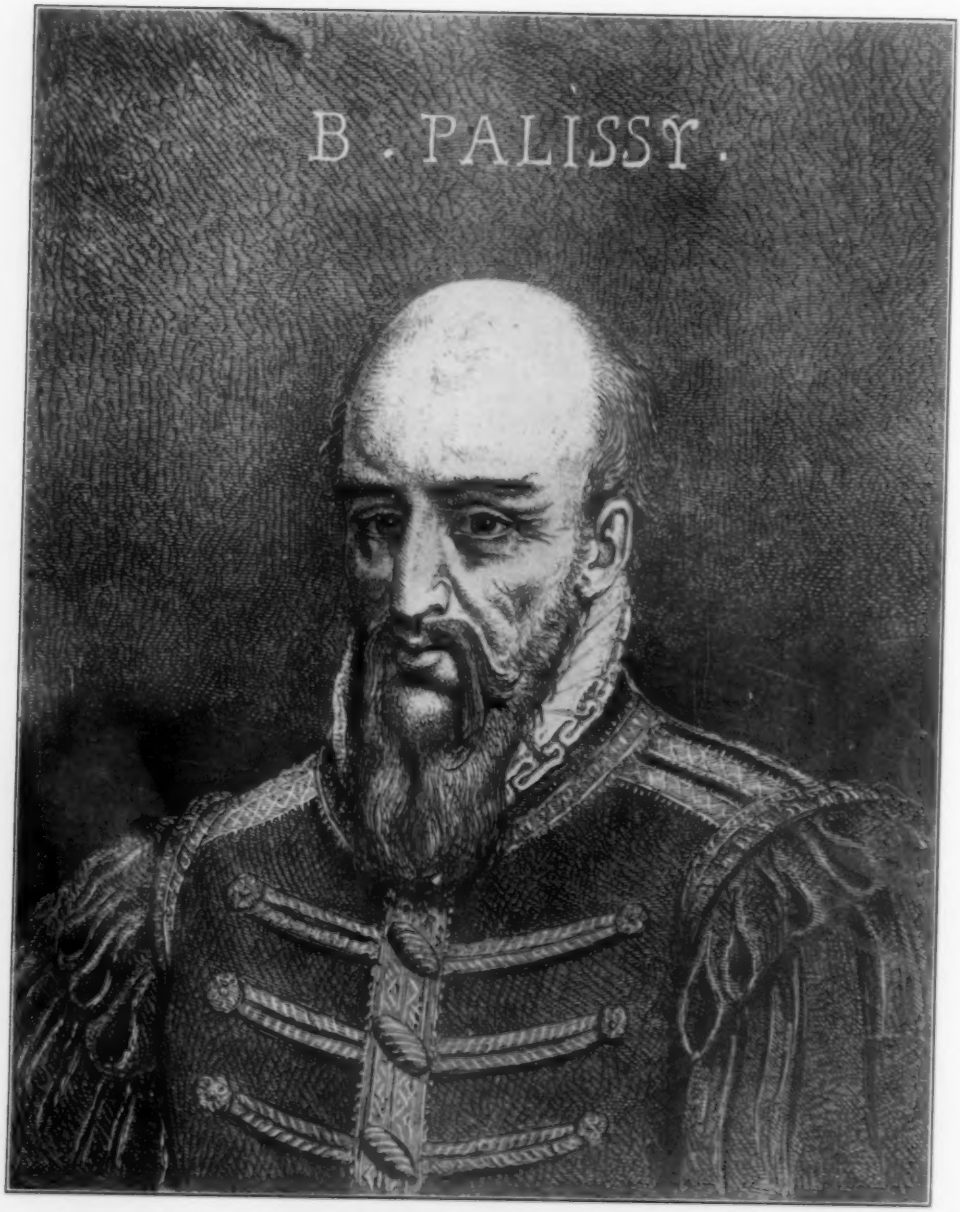
AN OAK RIDGE

WITHOUT UNDERGROWTH ON THE COASTAL PLAIN; THE OAKS ARE FESTOONED WITH SPANISH MOSS (*Tillandsia*).

Among the larger things in the coastal waters are the green sea-turtle, the giant logger-head, weighing sometimes as much as five hundred pounds, a large variety of sharks, the saw-fish, the tarpon or silver king, dolphins and the giant devil-ray or manta, weighing several tons. The catching of this last is considered the climax of sport.

In northern and central Louisiana we have several great river valleys and dry lake bottoms with extensive hardwood glades. We have a bluff formation composed of a light powdery soil and also characterized by hardwood forests. In southwestern Louisiana we have an extensive prairie or grassland region with its typical prairie life. Both in east and west Louisiana we have extensive flat or rolling pine lands traversed by clear sandy or gravelly spring-fed streams. Here live the cotton-tail rabbit, the fox squirrel, the gray fox and the timber wolf, the wild turkey and the bob-white, while the woodcock and other upland migratory birds winter in great numbers.

We also have other sorts of regions in Louisiana, but I have said enough to indicate to you how varied and interesting is the wild life of the state and also how different it is from the wild life in other states.


B . PALISSY .

AGRICULTURAL OBSERVATIONS OF BERNARD PALISSY, THE HUGUENOT POTTER

By GRACE M. ZIEGLER

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At a time when much of scientific belief was founded on conjecture and when education was thought to be for the rich, Bernard Palissy, the son of a poor workman in glass, attained distinction as an artist, potter and naturalist. Although his name is chiefly associated with his pottery work, his "pieces rustique" and other ware being valued at excessive prices, his conclusions in the field of nature won for him an outstanding place among the naturalists of the sixteenth century. His theories on agricultural practice, as told in his discourse on "How to grow Rich in Farming" and in other writings, show the accuracy of his observations and have earned for him a place among the earliest leaders of scientific agriculture. His perseverance throughout a period of direst poverty and in spite of the reproaches and ridicule accorded him by his acquaintances and even by his family while experimenting in the making of enameled ware, and the persecution he suffered on account of his religious beliefs, were such that, according to M. de Lamartine, "he has exercised an influence on civilization, and has deserved a place to himself amongst the men who have ennobled humanity."[1]

Born about 1509, probably in a hamlet near Agen, France, Palissy first became a glass painter. Not being satisfied with copying the patterns given him, he began as a youth to draw his own designs, preferring objects of nature and his mother's face as subjects. Having gained considerable knowledge of geometry, the natural sciences, drawing and painting, at the age of eighteen he embarked on his own career, traveling for ten or twelve years throughout France, in Flanders and on the Rhine, and adding to his store of information. That the sum total of his knowledge was acquired through observation is shown in his own words, "I have had no other books than Heaven and Earth, which are open to all."[2] In 1539 he married and settled in the town of Saintes, where he resided until he was imprisoned for heresy.

Many of the writings of Palissy are in the form of dialogue, to "procure for the discourse more ready comprehension," one person, "Theory" to inquire and "Practice" to reply. He believed it his duty to record the history of the troublous times through which his country was passing and also the knowledge he possessed on the various subjects which had occupied his attention. His love of nature is interwoven in practically all his endeavors, even his idea of creating beautiful pottery being to embellish the objects with specimens of nature—frogs, lizards, fishes, snakes, beetles, butterflies, shells and plants.

In "How to grow rich in Farming," the need for intelligence in farming is emphasized in characteristic manner: "I see so much error and ignorance in all the arts, that it seems to me as if all order were for the greater part perverted, and that each labours on the soil

[1] "Palissy, the Huguenot Potter," by C. L. Brightwell, Phila. 1858.

[2] "Palissy, the Potter," by Henry Morley, London. 1852.

without any philosophy, and all jog always at the accustomed trot, following the footsteps of their predecessors, without considering the nature or the prime causes of agriculture . . . I tell you, that there is no art in the world, in which a greater philosophy is required than agriculture; and tell you, that when agriculture is conducted without philosophy, it is the same thing as a daily violation of the earth, and of the things which she produces; and I wonder that the earth, and the natures generated in the same, do not cry vengeance against certain murderers, ignorant and ungrateful, who daily do nothing but spoil and waste the trees and plants without any consideration."

On the subject of impoverishing the soil by the extraction of potassium carbonate through cropping, Palissy was many years in advance of scientific research. His theories of replacing the salt, as propounded in the above-mentioned discourse, indicates that he had reference to potash salts. He asks, "Have you not seen certain labourers who, when they wish to sow a piece of land two years successively, set fire to the stubble or straw remaining from the grain which has been cut; and in the ashes of the said straw will be found the salt which the straw had extracted out of the earth, which salt, remaining in the field, will aid the land again; and so, the straw being burnt in the field, it will serve as manure would, because it will restore the same substance which it had extracted out of the earth." It is now well known that most of the potash absorbed from the soil by plants remains in the straw or stems and that little is contained in the grains.

To prevent the washing away of "salt" from manure by rains, he advises that a pit be hollowed, paved with flints, stones or brick, well plastered with mortar, and protected from the rains and sun by some sort of hut, for "when placed outside the stables, without any consideration," he says, "take notice in a time of rain, and you will see that the waters which fall on the said muck-heaps, carry away a black tint in passing through the said heaps; and finding the base, slope, or inclination of the place on which the heaps are put, the waters which pass through the said heaps will carry away the said tint, which is the chief part and whole sum of the substance of the muck-heap, for which reason the muck-heap so washed can serve only for a parade; but being carried to the fields, it there yields not any profit." As two thirds of the potash in manures is now known to be in a soluble condition, the best farm practices protect manure against loss from leaching by providing tight floors and shelter from rains.

A study of Palissy's reasoning with respect to salts in wood ashes is especially interesting, particularly in view of the fact that until the discovery of the Stassfurt salts in 1864, the principal source of potash salts was hardwood ashes. He says, "I venture to tell you afresh, and to maintain daringly, that there is no plant, nor kind of herb upon the earth, which has not in itself some species of salt; and tell you further, that there is no tree, of whatever kind it may be, which does not accordingly contain some of it, some more, some less. . . . Take notice of the smoke of wood; for it is so that the smokes of all kinds of wood make the eyes smart and injure the sight, and this because of certain salsitude which it draws from the wood, when the other humours are exhaled by the vehemence of the fire, which chases the hurtful and humid matters: and that this is so, you will recognize when you cause water to boil in some cauldron; because the smoke from the said water will do no harm whatever to the sight, though you present your eyes over the said smoke."

Again, he tells of some laborers who manure their fields with a kind of earth called marl, which they find of more value than dung. He promised "If I see that my writings are not despised, and that they are put in execution, I shall take pains to seek for the said marl in this region of Xaintonge, and will make a third book, by which I will teach all people to know the said marl, and even the method of applying it to fields, according to the way of those who are accustomed to its use." This pledge he afterwards fulfilled.

Especially to be deplored was the indifference of farmers regarding the tools and implements which might lighten the labor of agriculture and increase the production: "I wonder at the ignorance of men, when I look at their agricultural implements, which ought to be in more request than precious bits of armour. . . . I could wish that the king had founded certain offices, estates, and honours, for all those who should invent some good and subtle agricultural tool." These and other utterances far in advance of his time fill many pages of the potter's writings.

Palissy's persistent search for the method of making enameled pottery gives us a vivid picture of the caliber of the man. Since glass-making was practiced by many people of little skill, only a very meager living was to be obtained therefrom. His other means of livelihood, land surveying and portrait painting, were only in occasional demand. Chancing to see a beautiful Italian cup of enamel, he was inspired to make the production of enameled ware his life work, believing that his skill in drawing would enable him to produce objects of great beauty. At this time there was no enameled ware produced in Europe outside of Italy, but nothing daunted, and without knowledge of the baking of earth or of the materials of which enamels were composed, he set to work confidently to discover through experimentation the methods of its production. His family, together with his pecuniary difficulties, prevented a few trips that might have saved him many costly and disheartening mistakes. For sixteen years he bent his energy to this end, his life during most of this time being one of extreme wretchedness and poverty. Many children were born to him, all were undernourished, and six of them died. At one time he was compelled to burn the palings of his fence and his tables and flooring of his house to maintain sufficient heat to finish a trial lot. Twice he was near the verge of despair, and was compelled to turn to other employment to provide the necessities of his family. The first time he received a commission from the government to make a survey of the islands of Xaintonge and the district of salt marshes to establish the gabelle, or tax, on salt, and the second time he replenished his finances by painting.

It took Palissy about eight years to discover with certainty the process of producing white enamel, which he considered the basis for all enamels, and during the succeeding eight years he found to his surprise and sorrow that there were many other things unknown to him. Accidents befell him in many ways—ashes flew against his vessels and mingled with the melted enamels; the mortar of a furnace he built was full of flints, which burst into pieces when heated, spattering his work and becoming hardened with the enamel; his vessels were baked too much or too little, or they were baked properly in front but not baked at all behind; sometimes the enamels were put on too thinly, and sometimes they were too thick; and when there were enamels of different colors some were burnt before others had melted. There were difficulties in the choice and management of clays.

His sufferings, and his courage, are shown in occasional paragraphs of his writings. When one of his trials was about to be completed, many of his creditors came to watch the result. According to Henry Morley, "He had expected three or four hundred livres. 'I received,' he says, 'nothing but shame and confusion; for my pieces were all bestrewn with little morsels of flint, that were attached so firmly to each vessel, and so combined with the enamel, that when one passed the hand over it, the said flints cut like razors. And although the work was in this way lost, there were still some who would buy it at a mean price; but, because that would have been a decrying and abasing of my honour, I broke in pieces the entire batch from the said furnace, and lay down in melancholy—not without cause, for I had no longer any means to feed my family. I had nothing but reproaches in the house; in place of consolation, they gave me maledictions. My neighbors, who had heard of this affair, said that I was nothing but a fool, and that I might have had more than eight francs for the things that I had broken; and all this talk was brought to mingle with my grief.'"

It was during the lifetime of Bernard Palissy that Martin Luther founded the basis for the Protestant religion in Germany, and about the time Palissy succeeded in pottery-making Calvinism had gained considerable headway in France. Characteristically, Palissy set out to determine religious truth, and having reached a conclusion nothing could alter his determination to stand by it. At his instigation a group of six men, including himself, was formed to worship secretly in accordance with their belief, each taking his turn at preaching to the other five. This was the beginning of what later proved to be a large congregation of the Reformed Church at Saintes. Palissy describes the horrors of this time, when first the youth, Charles IX, and later his brother, Henry III, became king of France, but their mother, the treacherous Queen Catherine de Medicis, was the actual ruler. There were two political factions, one headed by the Duke of Guise, who was the leader of the extreme Catholic party, and the other by Constable Montmorenci, of more liberal tendencies, with the Queen endeavoring not to offend either party but to hold them so well balanced that she might sway either as she pleased. Although heretics were constantly being burned to death, Palissy believed himself safe because of the interest of his friend and patron, Montmorenci, who had issued orders that the artisan be protected. However, in 1562, he was imprisoned at Bordeaux, but was released on the plea of the Constable by Queen Catherine, whose redeeming trait seemed to be her interest in art and literature. The potter was appointed by her as "workman in earth to his majesty," his task being to adorn the gardens of a new palace, the building of which was then engaging the attention of the queen-mother.

While engaged in this work and in pottery-making in Paris, Palissy decided to test his theories on agriculture, chemistry, mineralogy and geology by subjecting them to criticism. This he accomplished by delivering in his own museum, over a period of nine years, the first series of lectures on natural history ever given in that city. To secure the most intelligent audience he charged a dollar admission, knowing that if he spoke falsely "there would be Greeks and Latins who would resist me to my face, and who would not spare me, as well on account of the dollar I should have taken from each, as on account of the time I should have caused them to misspend." He adds, "Thanks be to God, never man contradicted me a single word." His audience consisted of

"many skilful physicians, celebrated surgeons, grand seigneurs, gentlemen, and titled ecclesiastics, also some of the legal profession, and others, who were drawn together by a common love of scientific research." The favorable opinion of these judges has been confirmed by Haller, Cuvier and others, while many of his theories have withstood the light of scientific investigation although founded on no better basis than observation.

Continuing his heretic activities, Palissy was again arrested in 1587, thrown into the Bastile and condemned to die. Execution was delayed by the artifice of friends in power, and the king on a personal visit offered him liberty if he would renounce the Protestant faith. This he refused to do, preferring rather to die at the stake. He escaped this torture, however, dying in 1589 before the sentence was carried out.

Various editions of the works of Palissy appeared in France, in 1563, 1580, 1636, 1777, 1844, and a Dutch edition, said to have been published at Amsterdam, made its appearance in 1655. His writings include discourses on farming, chemistry, geology, forestry, experiences in pottery-making, kinds of clay, the trials of the earliest Protestants and other subjects of his investigations and experiences, and his book entitled "A Trustworthy Receipt, by which all the Men of France may learn how to multiply and Augment their Treasures" treats of agriculture, natural history, a "delectable garden," and a "fortified town."

THE LIGHTS AND SHADOWS BACON THREW ON SCIENCE IN THE NOVUM ORGANUM

By Dr. JONATHAN WRIGHT
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In the year the Pilgrims landed at Plymouth, Bacon published the *Novum Organum*. In every field of human endeavor certain figures stand forth preeminent in the perspective of its history. Certain of them it is thought, owe their preeminence to their environment. Others are credited with making the environment. There is an ebb and flow to beliefs of this kind among men who know history. As the world lurches toward socialism its opinion is that one man stands on another's shoulder and the environment makes them both. As the world politics marches toward conservatism and the rule of one or a few, historians are busy with the pedigrees and loudly proclaim the man is the epoch. He has made the world which follows him. He has had it in him bred from a line of men of talent. There is an ebb and flow to these world currents which drag one another along. The facts remain the same. The opinions, however, are purely subjective and the facts are twisted, at one epoch and the other, to jibe with them. Francis Bacon lacked neither in his heredity for good blood, as the world judges it, in his veins, nor for the aid of his environment, nor for the stimulus of small means. His environment was one in which the kind of talent he possessed and the lack of honesty and lack of personal regard for a man's honor, which is a part of it, helped him to high office in the state, just as such things do men now. His hands were soiled with bribes given and bribes taken, but so were the hands of his comrades.

All this is not essential for a consideration of what he did for science in the history of thought, but still it would be useful to study it more in detail if space allowed. We might find that lack of money stimulated him to exertions which made him great in public affairs, but we lack any perception of why that should have made him great in science and a great figure in the history of thought. Despite the lack of evidence we have every reason to suspect, from what we know of psychology, that the habits of industry and persistence which the lust for place and pelf magnified in his heredity, played their part in that heritage of science he transmitted to posterity. These made a link between his political life and his intellectual, perhaps which, even in such a cursory essay as this, it is not well to lose from sight.

He was a courtier before he was a censor, but it is in a very censorious way he starts his great work, the "Novum Organum"[1] and we need not fail to find the trail of the tricky politician, the last of places where disingenuousness should show its serpent's head. Dogmatism is his first charge, but the further one reads in the introduction there appears no lack of dogmatism in Lord Verulam himself. He is very severe on the Ancients. In their theories they were intolerant and by persisting in their errors

[1] Of the many scores of editions of Bacon's *Novum Organum* those of Dr. Shaw, 1813—London, and of Joseph Devey, 1902—New York, are the sources of the following remarks, with references to Devey's more recent translation.

they won adherents and they enslaved the minds of their fellow men. It was the sophist of old, who drew Plato's fire and it led to the sophists' lasting and largely undeserving damnation. It was they who followed the Nature philosophers in the evolution of Greek science and it was the sophists who were Bacon's especial antipathy. He joined in the hue and cry he found echoing through the ages to his time and beyond. The world has never paid properly the debt we owe to the men who pointed out the fallibility of the senses and the errors in their own reasonings. They were the first analysts of thought who followed the faulty observations of the nature philosophers and their crude theories, but Bacon thinks of the latter as occupying a prudent place between the arrogance of despotism and the despair of skepticism, and prudence was the deity the courtiers of the court he knew, honored most and most pursued. Bacon draws the to him all sufficient moral. These sophists fell into difficulties when they came to doubt their senses. For Bacon it was folly to follow reason into difficulties. You will search his maxims in vain for the exhortation to "hew to the line and let the chips fall where they may." If a man flinches in the face of philosophical difficulties in thought, his thinking may be safely neglected. There is none of this in Plato and none in Aristotle. They were not favorites with Bacon and he detested Protagoras and his philosophizing and was gratified to think the nature philosophers were content to put the senses to the test.

Bacon himself may perhaps be cleared of skepticism, but he can not escape the inferences of readers as to his dogmatism and arrogance. In his prefatory remarks he says his doctrine or rather his method "consists in determining the degrees of certainty while we as it were, restore the senses to their former rank." Physics especially, but many another territory in the domain of science, would have been led far less widely astray today than it is if the senses alone had been depended on, and if man generally for long had neglected "that operation of the mind which follows close upon the senses" the paths of science would have been narrow indeed. We may still be as open as Bacon was to the charge of arrogance, especially when we think we have just made a long step forward, but instead of being in the "despair of skepticism" we are all not only cheerful, but, despite all, fairly hopeful of the continued progress of science from the results thus far attained in an era when skepticism is rampant. We are disinclined, however, to calculate for the future with any degree of certainty because of Bacon's method or any other in science. Skepticism has saved us from many a despair over the wreckage of a hope, much more over that of a "certainty." Two generations ago Claude Bernard,[2] quoting de Maistre, agreed "that they who make the most discoveries in science know Bacon least, while those who read and ponder him, like Bacon himself, have poor success." Today a distinguished countryman of Bernard remarks[3] that most physical laws, as we now use them, do not belong to the intuitive maxims of $2 \times 2 = 4$, nor the sum of the three internal angles of a triangle equals two right angles, but belong in the category of the laws of probability (not of "certainty") and he quotes the English Quaker Jeans with approval for saying that if you put water on the stove it *may* freeze, but the probabilities are it will boil. Unfortunately there are some physical laws not so secure in their probabilities. A much larger margin is left for skepticism even as to the conservation of energy and the indestructibility of matter.

[2] "An Introduction to the Study of Experimental Medicine," translated by Henry Copley Greene. New York, Macmillan, 1927.

[3] Borel, Emile: *Revue Scientifique* No. VIII, 23 Avril, 1927.

Skepticism flourishes, but hope is not dead. Dogmatism is not so rampant as we find it in Bacon's works, 300 years now after they were first published. We have long since abandoned much of his doctrine, just as we have abandoned much of the formal logic of the old *Organum* of Aristotle. We have abandoned, it is true, much of the formalism and pedanticisms of the Ancients, but the old methods the mind employed in arriving at conclusions persist. Perhaps he was right in asserting that the old scholasticism was fatally erroneous in starting from one supposed fact and by syllogisms clinging to it until a logical conclusion was reached, but it is not at all clear that the natural mental process is radically different when it permits the intrusion of new facts in the chain of logic. That all logic, that every syllogism, is to be banished from the method of science is worse than the worst of the ancient Aristotelian procedure, except for the fact that it is impossible for the mind to work at all and automatically casts it loose to find a compromise.

As for the fallibility of the senses, without perhaps going to the extreme of denying it, indeed he acknowledges it (I.LXIX), he restores them to their position of trust, as Epicurus did, by the mere violence of assertion. They are the only guide we have to direct us, it is true, but he fails entirely to combat the arguments, which the ancients used to dethrone them, and his strictures on those who doubted their reliability are entirely disingenuous. Once taking note of his tendency to this, the reader has every reason for skepticism in the face of his expositions of doctrine, just as the student of nature has every reason for a wary attitude in the face of its problems. This need of caution, this uncertainty is inherent in every problem the man of science thinks he has solved. The greatest of them all, boasting he made no hypotheses, Newton's physics have gone into the discard as expositions of reality. They are and perhaps will long remain useful formulas on earth, but the equations of Euclid and Newton's physics no longer have final values. They are true enough thus far for the man in the street, but they remain no longer a model for the "certainties" of science. There is then full justification to be found in the history of science for the skepticism with which Bacon reproached those who had gone before him. Those who came after him, enthusiastic and eulogistic appraisers of his methods, have gone astray in spite of them if not with them. Perhaps we can do no better than this, but we should remember it when we survey Platonic transcendentalism, for verily all knowledge here below appears based on illusions. Bacon has not presented us with an impeccable alternative on declaring that the system of logic prevailing before him "is useless for the discoveries of the sciences" (I.XI) against which exaggerations even the most partial of modern editors protest, and though nominally we have discarded logic, practically we use it daily in unconventional forms. We may err in the use of it, but no more than we daily do in the pursuit of facts by observation and experiment.

It is the marvel which raises numbers to the level with the divine which is expressed in the common phrase that figures do not lie. Deductive reasoning we know from Bacon is always digging pitfalls of error for science, but Claude Bernard assures us that errors of scientific theory most often originate in errors of fact. Mathematical equations, when freed from physical hypotheses, are a sort of reasoning—a reasoning free of error, with which Bacon was unacquainted. Free from error, observation and experiment never are. This part of his message to the world Bacon subjected to no sincere analysis. It is curious to find him so deprecatory of Aristotle's books on animals. One scarcely knows what he means in the assertion (I.LXIII)

that the old Greek had frequent recourse to experiment in them. It is difficult to find an instance of it, unless we associate the concept of experiment with observation, a practise more common in the writings of Bacon's day than in those of our own. Aristotle's observations on animals have hardly been surpassed, relatively, by modern zoologists, but he has not been credited with experimental methods. In one of his books on animals[4] he treats the matter of method thus: "Ought the writer who deals with the works of nature to follow the plan adopted by the mathematicians in their astronomical demonstrations, and after considering the phenomena presented by animals and their several parts, proceed subsequently to treat of the causes and the reasons why? Or ought we to follow some other method? And when these questions are answered there yet remains another. The causes concerned in the generation of the works of nature are, as we see, more than one. There is the final cause and there is the motor cause. Now we must decide which of these two causes comes first, which second. Plainly however that cause is the first, which we call the final one." On this assumption all antiquity proceeded and it was largely Bacon who reversed the order and tried to reach the final cause by beginning with observations of the "motor cause," but neither he nor his successors have ever reached the Final Cause. Aristotle goes on: "For this is the reason and the reason forms the starting point alike in the works of art and in the works of nature. For consider how the physician or how the builder sets about his work. He starts by forming for himself a definite picture." In illustration of how much we have disregarded Bacon and how nearly we have reapproached Aristotle in our ideas of the way thought runs I quote a review in *Nature*[5] by H. E. Armstrong. In biology it is especially true but even in chemistry "to experiment usefully the motive of the experiment must be first visualized and must be logically considered. . . . judicially interpreted with logical precision." After several centuries of Baconian doctrine this has become a commonplace sentiment of men of modern science. That is what the mind does before it *begins* to experiment and investigate. Whether the attention is first directed toward the problem or not, there is no problem for the mind until that picture is formed, however vague its outlines may be. "In the one case," Aristotle says, "it is perceptible to mind, in the other to sense—(a definite picture) of his end, the physician of health, the builder of a house—and this he holds forward as the reason and explanation of each subsequent step." One may well doubt if Bacon had this text before him when he wrote in condemnation of Aristotle and all his works. It may be well conjectured he had before him the twisted and contorted and corrupt readings of a lot of lazy monks and orientals.

Aristotle in showing the way by which the mind or rather its processes can be analyzed and understood never dreamed, we may be sure, his exposition could be used in the annihilation or sterilization of efficient thought, but such was in a large way the result in the Middle Ages. "The scholastics, it is true, abused the deductive syllogism by employing it in its naked, skeleton-like form and confounding it with the whole breadth of logical theory; but their errors are not to be visited on Aristotle who never dreamed of playing with formal syllogisms" in the prosecution of science. It is one of the modern editors of Bacon who thus speaks when in the "Novum Organum" (I.LIV) Bacon charges Aristotle with making his "natural philosophy completely subservient to his logic." Bacon is evidently pretending he has read what he never saw in Aristotle.

[4] De Partibus Animalium 639 b 5. Oxford transl. by Ogle 1911.

[5] September 24, 1927, p. 433.

There is not even a suggestion in his "History of Animals" and the long quotation I have made above from his "Parts of Animals" lays bare the synthesis of his thought far removed from any formal logic and illustrative of the way the mind of man works when he thinks. Yet Bacon makes the false assertion not once but twice (I.LXIII). Aristotle had different compartments in his mind for different things and Bacon had evidently never read enough of his real works to know it. He depended on the scholastics of the Renaissance and the Pre-Renaissance for his ideas as to Aristotle, made up in their turn from miserably corrupt texts of Arabian provenance. Bacon may indeed have had an idea of the way the human mind works, but his chief preoccupation seems to have been with the way he thought it ought to work. Yet his own inductive method did much, a very great deal indeed, subsequently to guide the natural mind of man into more profitable ways of working, to broaden the bases on which it must work, but without deductions, theories, hypotheses, it will not work at all and this Aristotle well understood. Apparently neither Bacon nor Newton did. They may have thought so, but there was nothing wrong with Aristotle except the Aristotelians who preceded Bacon. Bacon as well as the Baconians were largely in error, not only as to Aristotle, but as to the natural workings of the human mind.

The conjecture is entirely warranted that, preposterous as it may seem, Bacon was jealous of the place Aristotle still held in the world of thought. "Aristotle himself," he remarks parenthetically, "so distinguished a man and supported by the wealth of so great a king, has completed an accurate history of animals, to which others with greater diligence but less noise have made considerable addition." (I.XCVIII) Despite the narrowness of his soul Bacon had a width of intellect and an acuteness of perception which are unmistakable and undeniable. So apt is he to point out the supposed errors of Aristotle he falls at times into errors himself where Aristotle had found the way to truth. There are others, but his disquisition on sound (II.XLVIII) is an instance where Aristotle following the still more ancient opinion of Alcmaeon has found support and Bacon has found contradiction in modern science.

Bacon, as has been said, may indeed be credited with broadening the bases of science and let no one belittle that service—one of the greatest contributions to the efficiency of human endeavor recorded in the history of thought, but he in no way changed the nature of its basis nor the course of its activity. He moved men greatly to enlarge it, so that no longer as in antiquity its axioms were henceforth to be derived from "a scanty handful of observations" (I. XXV), but, though all of them possibly have their origins in the senses, they are as fallible as those unquestionably arrived at chiefly by the help of reason. It may be remarked that it was not alone Aristotle in the absence of instrumentation went astray with the doctrines of Eudoxus and Calippus, but despite the vastly more correct work of Kepler, of which Bacon might have taken advantage, Bacon felt privileged to build grotesquely erroneous astronomical theories of his own. Jaeger thinks Aristotle's troubles with his astronomical theories drove him to despair. Bacon at least had a thicker skin, having been most of his life a politician, but he understood far better than the ancients the vice of dogma in all logic and the utility in the testimony of controls both of reason and observation. In his day much more than in our own, though still in our own, "this evil insinuates itself craftily in philosophy and the sciences and vitiates every conclusion" (I.XLVI). If his followers had heeded this admonition as much as they did his

objurgation to abandon deductive reasoning science to-day would have been vastly better off. For we need to go back over the history of thought scarcely a hundred years when Bacon dominated it all. Men of great influence upon it read Bacon "a page a day and he was their great light in all things."

The utilization of controls, which we owe to Bacon, we may well boast is the frequent resort of the best workers in modern science, but it is frequently neglected, especially in biology where it is most of all necessary—in medical research. A thousand patients every day are credited with being cured by Dr. Blank's remedy, but none may know how many get well without any "cure" at all. Unfortunately it is not in therapy alone, wherein we all expect to be and usually wish to be humbugged, but it is so in very fundamental fields of medical research and it has led to absurd fads and divagations of the mind, manifold exaggerations of the imagination and heedlessness of the oblivion which falls upon the old when a new aberration appears. The human mind is and has ever been more moved by affirmation and blind to negation. In this respect neither the maxims of Bacon, which warn us, nor the admonitions of wiser experimentalists since his time have markedly affected the proneness of man in this particular to err, but Bacon's chief emphasis was laid upon the errors of deduction.

Before and after Bacon Democritus and Dalton arrived at a conception of atomic structure only long enough subsequently to be established experimentally. The theories of both were entirely deductive and from Sir Joseph Thomson's own avowal we are driven to the conclusion that was the initial process in his own mind when he arrived at the belief the atom could be split into electrons. There were many things afloat in the air of our time, which may well have suggested to a mind so alert the existence of still further divisions of matter, just as now we are beginning to hear imaginings of "dust" on the electrons. We have much evidence in history that there was a sentiment arising among learned men in revolt against the scholasticism Bacon so much criticized when the first James, as learned as any of them, but not so progressive as some, sat on England's throne. Indeed the *de Magneto* which Gilbert, who was court physician to both Elizabeth and James, wrote contains repeated assertions of the advantages of the experimental system. He must have lived on well into the life span and in the environment of Bacon. Before Bacon as he was in this, so also he had a far more correct perception of the celestial mechanics of Copernicus. Bacon after depreciating the ancient nature philosophers, both as to method and attainment, may be said to have placed Copernicus and Kepler in the same class with Ptolemy and Xenophanes, as his editor again suggests, though Kepler had swept away their "futile and false theories." So excellent did Bacon, notwithstanding his ignorance of much of the science of the day, judge his method of studying it that he declared he left little to any acuteness of mind and strength of will to perform (I.LXI). He seemed to think he was largely diminishing the demand for wit and intellect.

He disclaimed any intention of boasting, but one hardly knows what else to call it when he says: "Let those who distrust their own powers observe myself (forsooth) one who have among my contemporaries been the most engaged in public business, who am not very strong in health (which causes a great loss of time) and am the first explorer of this course following the guidance of none," (I.CXIII)—except, we might add Gilbert and the other Bacon and Paracelsus and many others—I am unaware of anything so naively complacent recorded elsewhere in the history of intellectual achievement. Ignorance of the history

of science easily makes the wisest of us an ass. At this place he is apparently referring not alone to some specific material contributions of his own to the solid results of science of which he certainly had little enough to boast, but astonishing to say, he seems to entertain the view he was the first to engage in the pursuit of knowledge by experimental methods and observation. His investigations into the nature of heat were a complete failure, though it is still not an entire success as investigated experimentally by modern physicists. He was somewhat more successful in dealing with the ebb and flow of the tides (I.XXXVI) going astray perhaps only because he knew nothing of the law of gravitation, first demonstrated long after him, nothing of much of the astronomy of his time and long before. Likening the force exerted on the water of the sea to the action of the magnet, which in the way of a marvel had been cited by most writers since Homer, he is sometimes said to have antedated Newton in exposing the physics of the phenomenon. Many of his further ventures into the objective activities of science were not attended by the results he promised others from the use of his methods.

But for all this we owe a large debt to him if only for that exaggeration of the benefits of his method. Science usually makes its strides forward in this way, forcing the emotions rather than the intelligence of men into absurdities and veritable distortions of thought, while panting after the faint glimmer of light pointed out usually by more moderate men, but Bacon was not one of these. It was he, however, who accelerated that momentum which was inaugurated long before him toward a better balance, despite his own lack of it, in the methods of the thinking of men, pushing it into channels of more fruitful endeavor. His foresight in many directions was great. He was one of the few who foresaw to some extent the great part the microscope was to play in the science of the future, though he far underrated it (II.XXXIX). He emphasized and insisted on the value of such things, but his methods were in use long before him. Many of the medieval alchemists, long before the revival of what we call real learning in Italy, were constantly working with experimental methods. No one man began it, neither Roger Bacon nor Lord Bacon nor Paracelsus. The "method" had always existed, though many have talked arrant nonsense about it. Hippocrates experimented on the pig. Celsus tells us of the experimentation of Erasistratus. He tells us of the vivisection of men, an experimentation which is now done more humanely. Galen was probably the greatest of all experimenters in medical research.

The astrologers and the magicians were constantly experimenting in nature, though chiefly on the nature of man and man's credulity. Of this kind and of many other kinds akin to it experimentation is always going on. Even Bacon admits these people practised his methods (I.LXXIII), "rather tending to disturb than to assist experiment," he says, though he does not point out where experiment disturbs old fallacies and where it introduces new ones, but thereby "the alchemists have made several discoveries and presented mankind with useful inventions" (I.LXXXV), finally in our time giving us a glimpse of the actual transmutation of the elements. Yielding as he is to those fakirs of science in his day he has here a sterner word for "reasoners." In a covenanter of the next reign to that in which Bacon flourished his type of mentality would have been called bigotry: "When contemplation and doctrinal science began, the discovery of useful work ceased."

WAVE MECHANICS

By Dr. PAUL R. HEYL

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THE twentieth century has been a strenuous time for students of physical science. Its days have been made up of crowded hours. This is perhaps best realized by those of us whose elementary physical concepts were formed before the discovery of the X-rays. Perhaps as good a way as any to visualize the situation in which we find ourselves is to tabulate briefly (and not in chronological order) the various contributions which have been made to physical science by the first quarter of the twentieth century.

1. The Bohr Atom.
2. The Quantum Theory.
3. The Theory of Relativity.
4. The Equivalence of Mass and Energy.

To these must now be added a fifth—Wave Mechanics.

Looking over this imposing array one may perhaps be pardoned for recalling sympathetically the recent utterance of that English clergyman who suggested the advisability of a ten-year vacation in scientific progress to permit of catching up. But this can not be. The halts in the march of progress are but brief; the bugle blows and we must fall in. There are minds which have produced these new concepts and are restlessly pushing on to others; and there are many others who, if they can not lead, seem easily able to follow. The rest of us are confronted with the stern alternatives of keeping up with the procession or falling out.

These different concepts have not all been equally difficult to comprehend and assimilate. The Bohr atom in particular seems to have made its way into general understanding without a struggle. Perhaps this has been because the concept offers us a clear mental picture, analogous to something with which we are thoroughly familiar—the solar system, also because the mathematics of the subject is closely like the well-known celestial mechanics. Be this as it may, the Bohr atom is undoubtedly the most generally understood of all the newer concepts of physics.

The quantum theory has encountered more difficulty. Even to-day it is still at sword's points with the old established undulatory theory of light. Each of these concepts has its own field in which it is able to show a valid reason for existence.[1] As Lodge says, the two concepts are like a shark and a tiger—each supreme in its own element and helpless in that of the other.

The theory of relativity has encountered perhaps more vigorous "sales resistance" than any other of the newer physical theories. This has been principally because its concepts are of such a nature as to appear to many bizarre and fantastic to such a degree as to be repulsive, and discourage further investigation; and also because its mathematics, while not new, is (or was) quite unfamiliar to all but a few. Yet at the present time the theory may fairly be said to have fought its way to at least a tentative acceptance by the great majority of those qualified to express an opinion on the subject. As a result

[1] "Atoms of Energy." THE SCIENTIFIC MONTHLY, November, 1926.

of the recent work of Adams[2] on the shift of the lines in the spectrum of the companion of Sirius, the last doubt as to the verdict of the three experimental tests suggested by Einstein has been dispelled.

The doctrine of the equivalence of mass and energy, often known as the inertia of energy, is perhaps the best accredited of all the newer concepts, for it comes to us with a pedigree strictly classical, which can be traced back to Maxwell and Newton without bar sinister. This has been elsewhere set forth,[3] but we may briefly review the subject because of the similarity of the argument to that which has given rise to the theory of wave mechanics.

In brief, the argument is that we are confronted by a dilemma: either we must accept the new principle of the inertia of energy or we must abandon the older fundamental principles of mechanics. Now the latter are backed up by ample experimental evidence, and in consequence the new principle, though as yet without any direct experimental verification, rides into acceptance upon the credentials of the old.

And now, with hardly time to catch our breath, we face a new claimant for recognition—wave mechanics; a concept abstract in the extreme as compared with the Bohr atom, yet covering much the same ground, and claiming to do it better.

Simple and natural as the Bohr atom may appear, there is a serious indictment to be brought against it: it is not self-consistent. In order to make his atom work Bohr found it necessary to play fast and loose with accepted theory, discarding it where advisable and retaining it where convenient without any excuse other than necessity. For example, a charged particle such as an electron should radiate energy when revolving in a circle. Bohr says it shall not, but in the next breath admits that it shall radiate while changing from one orbit to another. No one is readier to admit this inconsistency than Bohr himself. His justification for it is that it works well, and it certainly does. The success of the Bohr atom in accounting for chemical and physical facts is almost uncanny. Upon the basis of these untenable assumptions Bohr and his fellow workers have erected a statue marvelously true to Nature, yet this statue has feet of clay. We tolerate it for lack of a better, knowing that it is doomed to fall as soon as a more logical and consistent substitute makes its appearance.

For these difficulties, as well as others less serious, the new wave mechanics offers a simple and logical explanation, and in what it has to offer we may perhaps recognize the first strokes of the handwriting on the wall.

This new concept is but little more than three years old. The first suggestion of it is due to Louis de Broglie.[4] It appears as though de Broglie, on looking over the array of new concepts produced by the twentieth century, had become curious to see what would happen if one mixed them, much as the beginner in chemistry ventures with more or less trepidation to mix the contents of several bottles. So de Broglie seems to have asked himself: "What if we applied the theory of relativity to the quantum theory or to the inertia of energy?" He tried the experiment. The smoke arising from the reaction obscured his vision for some time, but when it cleared away he saw that which he, and Schrödinger after him, have elaborated into the theory of wave mechanics.

[2] "The Present Status of the Theory of Relativity." THE SCIENTIFIC MONTHLY, July, 1926. "The Common Sense of the Theory of Relativity." THE SCIENTIFIC MONTHLY, December, 1923.

[3] "The Inertia of Energy." THE SCIENTIFIC MONTHLY, October, 1925.

[4] *Phil. Mag.* 47, 446, 1924. *Ann. de Physique* 3, 22, 1925.

De Broglie, in his second article above referred to, has set forth in detail the mental process which led him to his new hypothesis. The principle of the inertia of energy states that any mass of say m grams is equivalent to mc^2 units of energy, c being the velocity of light. And the quantum theory rests upon two fundamental ideas. Energy it regards as existing in bundles or discrete units, like atoms of matter; and with each such unit there is inseparably associated a frequency of some kind. The simplest way to picture this frequency is of course as a mechanical vibration of something, but the term frequency as here used is much broader in scope. It may refer to any periodic change, mechanical, electrical or transcendental.

The frequency of this periodic change is usually represented by ν and the quantum theory states that the energy of a quantum, or atom of energy, is proportional to its associated frequency, *i.e.*, represented by such an expression as $h\nu$.

Starting then from our particle of mass m, its equivalent energy may be represented either by mc^2 or by $h\nu$. Expressing this fact in the form of an equation:

$$mc^2 = h\nu$$

"Now," says de Broglie, "this equation refers to a particle at rest. What form will it take if the particle is in motion?"

For the appearance presented by a moving particle to a fixed observer we may invoke the theory of relativity. According to this principle, motion slightly increases the mass of a moving body and apparently slows down any frequency connected with it, as far as a fixed observer is concerned. Hence the above equation, true for a particle at rest, becomes untrue for a particle in motion, the left hand term increasing and the right hand term decreasing.

This unexpected result puzzled de Broglie for some time, but he finally saw a way out. There is a certain parallelism between the situation that thus confronted de Broglie and that which led Einstein to the formulation of the principle of the inertia of energy. In both cases a combination of recognized and well-evidenced principles led to a paradox, the resolution of which could be attained by introducing a new concept. There is, however, an important difference between the two cases. In Einstein's case there was but one way out; his move was forced. De Broglie was not so limited; the solution that suggested itself to his mind was not necessarily the only one possible, though nobody as yet has offered an alternative.

De Broglie's hypothesis was that every mass-particle was enveloped and surrounded by a group of waves (never mind of what) traveling with the particle as a sort of body-guard. Though the group keeps pace with the particle the individual waves constituting the group travel more rapidly, the waves dying out a little distance ahead of the particle and new ones coming into existence a little way behind. Just so successive generations of men pass rapidly across the stage of time while human progress moves onward more slowly. This phenomenon of "group and wave speed" is not new to physicists.

De Broglie found that in order to restore the balance in the equation for a moving body it was necessary to assume that while the mass-particle moves more slowly than light the individual waves of the group move more rapidly, the geometric mean of these two speeds being the speed of light.

Strange as this hypothesis may seem, it soon showed itself fruitful. One of the unexplained assumptions in the Bohr atom was that an electron, as it revolved about the central nucleus, might not keep at any distance from the nucleus

that it pleased. Certain orbits were permissible; the zones between were forbidden. Through them an electron might indeed pass, but in bond and without a stop-over. And Bohr specified a whole number relation connecting these different permissible orbits.

De Broglie's hypothesis led to a simple explanation for this. These atomic orbits are of very small dimensions. De Broglie pictured the electron (surrounded by its group of waves) running round and round in its orbit, the group of waves trailing behind and reaching before. With a very small orbit the wave train might join at both ends, completing the circle. Now if this wave-ring joined so as to make a good fit, crest meeting crest or trough meeting trough, everything would work smoothly; but if there was a misfit interference would be set up and no steady state would be possible. And de Broglie found that the condition for a perfect fit was identical with Bohr's whole number condition for permissible orbits.

But further study showed that de Broglie's hypothesis was unable to carry on its early promise, becoming involved in logical difficulties. However, this suggestion, coming under the thoughtful notice of Schrödinger, was the starting point for the much more consistent and fruitful hypothesis known to-day as wave mechanics.

Schrödinger said to himself: "If such a group of waves always keeps pace with the particle, why the particle at all? Let us see what may be expected to happen if we suppose the group of waves itself to be what we call the mass-particle."

As the first thing Schrödinger saw that it would be necessary to establish for this proposed "wave atom" a satisfactory and acceptable pedigree. He took down from the shelves of science, where it had been resting as a classic and gathering dust for years, a principle originally formulated by Hamilton, considered excellent in its day and always highly regarded by a few, though neglected by the many. Of this principle it has been said by Professor Edwin B. Wilson that it is "the most fundamental and important single theorem in mathematical physics." From it it would seem that the whole of ordinary mechanics is derivable, and from it Schrödinger derived an equation representing very much the same thing as de Broglie's group of waves. By reason of this pedigree and the mathematical relationships involved in it he was able to determine just how such a group of waves should behave under different conditions, and among other things he found that the motion of what may be called the "center of gravity" of such a bunch of waves would, according to the laws of wave propagation, follow exactly the same path as would a mass-particle under the laws of ordinary mechanics. Such a wave-group passing near a mass would be deflected just as though the law of gravitation acted upon it. And in following these laws the wave-group turned out to be more consistent than a mass-particle would be; for it is a remarkable fact, of which we have become fully aware only of late years, that the laws of ordinary mechanics are not applicable to mechanical systems of atomic dimensions; yet even in problems of this character the wave-mechanics proves itself useful, and its most interesting application is to the structure of the atom.

It will be remembered that some few years ago a good deal was heard of a rival to the Bohr atom suggested by Lewis and Langmuir, and known as the "chemist's atom," or the "static atom," as opposed to the kinetic atom of Bohr. Instead of electrons revolving in orbits the Lewis-Langmuir atom supposed the electrons to be nearly stationary, distributed in a regular pattern over the surface of an imaginary sphere, much as

Ptolemy supposed the fixed stars to be set in the celestial sphere. These electrons were considered to be in vibratory motion, but never to move far from their mean position. Whether this concept of the atom was intrinsically incapable of explaining things as well as the Bohr atom, or whether it only lacked sufficiently ingenious handling, it is a fact that this static model was never as fruitful as the kinetic atom of Bohr.

The Schrödinger atom also departs largely from the Bohr concept. It likewise contains no revolving electrons. Imagine a sphere of some material which may vary slightly in density. The simplest type of such a fluctuation will be a slight increase or decrease throughout the sphere as a whole. Let us suppose that the change in density is greatest at the center and next to nothing at the surface. This variation in density may be graphically represented as in Fig. 1.

FIG. 1

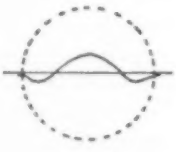

FIG. 2

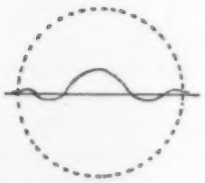

FIG. 3

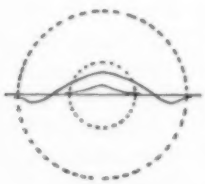

FIG. 4

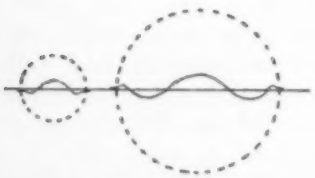

FIG. 5

If the sphere be smaller we may have a similar but more rapid fluctuation in density, just as a short string will give a higher note than a long one.

Again, there is the possibility that the vibration may be broken up into segments, as in Fig. 2 or Fig. 3. And it it possible that several of these modes of vibration may coexist in one sphere. This is essentially the structure of the Schrödinger atom; a sphere fluctuating throughout as a whole, either simply or in a complex manner.

A sphere of what? And what kind of a fluctuation?

Schrödinger postpones the answer to these questions for some time, but finally is forced to reveal the secret because of the impossibility of proceeding farther without it. Prior to this disclosure his differential equations speak only of the fluctuation of a mysterious, ghostly "ψ" throughout a spherical region of space. What is "ψ"?

Schrödinger's answer is a little roundabout and involved. ψ, as he has been using it in his equations is an algebraic complex quantity, involving $\sqrt{-1}$, and like all such complex quantities it has conjugate complex which he denotes as $\bar{\psi}$; and the answer is that

$$\psi\,\bar{\psi} = \text{electric density.}$$

The Schrödinger atom is therefore electrical in its fundamental nature, like the atoms of Bohr or of Lewis and Langmuir; but there is this distinction: whereas in the Bohr atom the charged electron moves in a circle, and in the Lewis-Langmuir atom vibrates slightly about a mean position, in the Schrödinger atom the electric charge is distributed continuously throughout a sphere, and (as we shall shortly see) is for the most part constant in density, but occasionally subject to slight fluctuations.

The test of the acceptability of any hypothesis is not its conventionality or its grotesqueness, its abstract or simple nature, but what it will do. Nothing in all science has appeared more fantastic

and unreal than the theory of relativity, yet it has made its way into general recognition because it was able to do things a little better than its predecessors.

The same is true of the Schrödinger atom. As we shall see, it is able to do everything which the Bohr atom does, and equally well; and in addition it offers a simple and unforced explanation of "permissible orbits and forbidden zones"; it shows how something in the atom may be in steady vibration without radiating, and how the atom will radiate only when it passes from one frequency of vibration to another. It has a chair empty and waiting for those troublesome things, half quantum numbers, that insist on rising like Banquo's ghost to disturb the feast in honor of the Bohr atom; and (what is regarded as most important of all) it performs easily a task at which Bohr threw up his hands —the calculation of the relative intensities of the lines of the spectrum. Such a newcomer is indeed welcome, though habited in strange dress. Perhaps its apparel is advance information of the coming fashion.

Schrödinger follows up the mathematics of the ψ-vibration and determines the law governing the form of the curves sketched in Figs. 1–3. He finds that any vibration of ψ will extend to infinity in all directions, but that for practical purposes the amplitude of this vibration becomes insensible at a radius of accepted atomic dimensions. Such curves as cross the horizontal axis one or more times (Figs. 2–3) do all their crossing within this radius. In mathematical language, the functions have a finite number of roots, all comprised within the ordinary radius of an atom. And (what is of prime importance) the number of these roots corresponds to what in the Bohr atom is known as the "radial quantum number."

A Bohr orbit may be circular or elliptic. For a circular orbit the radial quantum number is zero; for an elliptic orbit it is a whole number, the ellipticity varying with the size of the number. In the Schrödinger atom a fundamental vibration as in Fig. 1, with no crossing points, corresponds to a circular Bohr orbit, the radius of the Schrödinger sphere corresponding approximately to the radius of the Bohr orbit.[5] A Bohr atom containing two electrons in orbits of different diameters, one circular and one elliptical, would correspond to a Schrödinger sphere such as shown in Fig. 4, where two modes of vibration of different frequencies coexist, the vibration of higher frequency being practically confined to a sphere of smaller radius. The resultant vibration is of a complex form which need not concern us here.

There is in the Bohr atom another characteristic number called the "azimuthal quantum number," and the Schrödinger atom furnishes a corresponding number which does not lend itself readily to depiction or non-mathematical discussion.

The Bohr concept of an electron passing from one orbit to another of different "energy level" has its Schrödinger analogue illustrated in Fig. 5, where a vibration of high frequency, sensibly confined to a sphere of small radius changes to one of lower frequency, requiring a larger sphere to contain it. Both Bohr orbits in this case are elliptical.

Without multiplying illustrations, we may say that for every word in the Bohr dialect there is a corresponding term in that of Schrödinger. And since all the properties of the Bohr atom are expressible in terms of orbits, energy levels, quantum numbers and such like, the Schrödinger atom can perform all the tricks of the Bohr atom, and equally well.

Passing now to the deficiencies of the Bohr atom, let us see how the Schröd-

[5] The Schrödinger sphere having no sharply defined boundary this correspondence can not be other than approximate.

inger atom can contain a steady ψ-vibration without radiating energy. It must be remembered that ψ is not the electric density, but that the latter is dependent on ψ for its value. The mathematics of the subject shows that ψ may execute a simple vibration of any frequency and yet the electric density will remain constant. Classical theory therefore calls for no radiation.

But if the ψ-vibration consist of two simple components of different frequencies, the case is different. There will then of course be a beat frequency corresponding to the difference of the two component frequencies, and the equations show that there will be in this case a fluctuation of the electric density of this difference-frequency—and of course a corresponding radiation. This would give a spectrum of one line. And with more than two simple frequencies present, the number of lines in the spectrum will rapidly increase.

A simple ψ-vibration therefore corresponds to a dark atom. If this vibration changes into another simple vibration of different frequency the final result will be another dark atom; but during the change a single line will be emitted, for we must suppose this transition from one frequency to another to be gradual, not abrupt. The new vibration will doubtless begin of small amplitude, and gradually grow at the expense of the energy of the old vibration until the latter has disappeared. And during this transition there will be a beat-frequency and a radiation of energy.

The ease with which the Schrödinger atom lines up this trick with classical requirements is one of the prettiest things in all mathematical physics.

The Schrödinger atom does equally well with permissible orbits and forbidden zones. The mathematics of the ψ-vibration shows that the diameter of the containing sphere, while not sharply defined, is quite approximately so, and the different diameters indicated for the different frequencies follow a formula which roughly corresponds to the Bohr conditions for permissible orbits.

The half-quantum numbers and the intensity of the spectral lines in Schrödinger's interpretation are of rather too complicated a nature to permit of non-mathematical exposition.

For such happenings as "collisions of electrons with atoms" and "emission of electrons" Schrödinger's concept furnishes a ready mental picture. An emitted electron, according to Schrödinger, would be a little bunch of vibrations thrown off from a larger vibrating sphere, possibly to meet another such vibrating sphere and coalesce with it, either adding its energy to existing vibrations or contributing a new frequency to the atomic vibration.

The Schrödinger atom, because it will do more than the Bohr atom, is an improvement upon it and must supersede it; yet we must recognize that it has its shortcomings, and must sooner or later be superseded in its turn by some concept still more perfect.

One of these shortcomings is fundamental in the theory of wave groups. The existence of such a group, limited in extent, is possible only because it is composed of wave trains of slightly different frequency and velocity. These waves at certain points reinforce each other, giving the group, and at other points destroy each other, limiting the group. But no such group can exist alone. It must be one of a procession of groups all alike, and all traveling along with equal speeds, separated by regular intervals of space.

But it would be ungracious to dwell too much upon the weak points of a new theory which has already shown such real strength. Our part is rather to endeavor to assimilate that which is suggestive and fertile in the new concept (no easy task in a subject of such mathematical complexity), and having done this we may perhaps see clearly to cast out the motes that remain.

CAN BIRDS HOLD INJURIOUS INSECTS IN CHECK?

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UNIVERSITY OF ALBERTA

In this commercial age it would appear that the nature lover has failed to rise above the general trend of thought which views everything around us in the light of its possible financial value.

In days gone by we were accustomed to have a real affection for the many birds that greeted us each morning with their cheery song, or gladdened our eyes with their graceful flight, and were content to accept the pleasure that we derived from them without further question. Now, however, we are only too often asked to regard birds primarily in the light of whether they are liable to affect our bank balance and to guide our actions towards them accordingly.

This alone can be the excuse for the endless stream of articles and pamphlets from the pens of bird lovers who are all bent upon attempting to prove to their less esthetically-minded brethren that birds are money makers and that for this reason, above all others, they deserve our protection.

Unfortunately, in their enthusiasm to reduce our feathered friends to mere articles of commerce it would seem to me that many of these writers somewhat defeat their own object. They so smother the poor bird under the dollars and cents that he is supposedly producing that he is in danger of losing his time-honored status as a most welcome friend of man for his own intrinsic worth.

Extravagant claims are made regarding the financial debt that we owe to birds in their rôle of saving our crops from complete destruction by insects. Few of these claims can be supported by facts. A somewhat typical example of such claims appeared in a recent "official" publication. The writer contended that, in a somewhat limited area, birds destroy a daily average of 21,000 bushels of insects and, thereby, save this area from being transformed into a veritable desert. We have no desire to challenge the accuracy of this computation, but we do claim that the deductions that were made with regard to the significance of these figures are quite misleading in their application to the agricultural prosperity of the excellent farming district to which this reference was made. Were there no birds in that part of the country I venture to state that the agriculturist would not find that he labored in vain to produce a fitting recompense for his toil. It is possible, but by no means certain, that, in the case of a few of his insect foes, he might notice a slight increase in numbers. I am of the opinion, however, that his bank balance would not be sufficiently affected to make a "back to the land" policy the main topic of discussion in the local Legislative Assembly.

If an appeal to the pocket-book is a necessary plank in the platform for giving our feathered friends the protection that is due to them, by all means let us use it to the full, but among ourselves may we not enquire a little more deeply into its true significance? Should we convince ourselves that their financial

value is but a fraction of what has been claimed for them, we need be in no danger of lessening our interest in their protection but should rather raise it to a higher level which is based upon humanitarian and esthetic considerations.

In what I am about to say I lay no claim to being an ornithologist. As an entomologist, however, my duty leads me to study the causes which lead to the rise and fall in population among insect associations. This frequently brings me to the borderline of ornithology.

It would be wise if, at this point, we consider briefly the general factors which govern the abundance of insect populations.

As is well known, all forms of life have the potentiality for a very rapid and steady increase in numbers. This is well exemplified in the case of plant-feeding insects. The average number of eggs that are laid by the females of many moths or beetles, for instance, is in the neighborhood of three hundred. The majority have but one generation a year. A little calculation will give the potential progeny of such an insect at the end of, let us say, three years provided there is no mortality among her descendants.

Year		Eggs
First	1 pair (male & female)	300
Second	150 pairs. X 300 eggs	45,000
Third	22,500 pairs. X 300 eggs	6,750,000

Similar figures to these, some indeed smaller but others very much larger, can be applied to all of the thousands of different plant-feeding insects that inhabit our farms and gardens.

We all know, however, that, with comparatively few exceptions, each of our numerous different kinds of insects is present in approximately the same numbers from year to year. This can mean nothing but that, however many eggs the female of any species may produce, under normal conditions two only of her numerous progeny will reach maturity. In the examples cited 298 out of the 300 perish without reproducing their kind. This mortality, you will see, reaches the surprising total of 99.3 per cent. Should it drop, in the case of any such species to, let us say, only 95 per cent. for a few years, a severe outbreak of that insect is inevitable. On the other hand, if it were to rise, throughout the area occupied by that species, to 100 per cent., which is only .7 per cent. above the normal, the species would be exterminated for all time to come.

Very rarely do either of these contingencies arise. In recent years in Alberta, for example, among all our numerous plant-feeding insects, we have experienced wide-spread outbreaks of two species only. I refer to the grasshopper and the tent caterpillar. Were either of them due to the failure of the erstwhile active birds in destroying a due percentage of these insects? Was equilibrium finally restored by a subsequent superactivity on their part? The answer to both questions is decidedly in the negative.

Many factors, including birds, insect parasites, the direct effect of climate and local shortage of food, all take their toll of insect life. Among these the birds undoubtedly contribute a not inconsiderable share, under normal conditions, in producing the 99.3 per cent. mortality that is essential for the maintenance of an annual equilibrium in the population of these plant-feeding insects. In the case of a number of insects this has been shown to be about 10 per cent. Possibly this figure is somewhat below the average, but we shall see that it makes very little difference, in the long run, whether it be 5 per cent. or 50 per cent.

You will, I think, agree that the ex-

tremely delicate annual adjustment in the population of different species of insects must be controlled by some factor which is far more sensitive to the slight annual fluctuations in abundance, which inevitably occur among these plant-feeding insects, than can be the somewhat hit-and-miss attacks that are made upon them by birds.

We will, therefore, discuss this factor which is paramount in regulating the annual abundance of insects, and will then try to ascertain to what extent its operation is affected by the activity of birds.

As probably all of you are aware, for every plant-feeding insect there are from two to a dozen or more parasitic insects that live entirely at its expense. The simplest relationship between a plant-feeding insect, or "host" as it is termed, and its parasites can best be exemplified by the description of a specific instance. The common cutworm is known to support at least twelve different species of parasites, all of which are either flies or wasp-like ichneumonids. Since the ichneumonid form of attack is by far the more simple and direct we will consider the relationship between the cutworm and but one of its ichneumonid parasites and, for the time being, will disregard all of its associates.

Both the moth into which the cutworm matures and the adult ichneumonid are capable of laying about 300 eggs. Each species is, therefore, endowed with similar powers of extremely rapid increase in numbers.

The moth lays her 300 eggs in the fall. All being well, each of them will hatch into a cutworm in the following spring. At this season of the year, however, there have emerged, from overwintering cocoons, numerous adult ichneumonids. The females of these are armed each with a hypodermic needle-like ovipositor with the aid of which they are capable of planting their eggs deeply in the bodies of any cutworms that they may encounter.

Much as the cutworms prefer to remain below ground, where they are immune from the attacks of the ichneumonids, they are forced to come to the surface from time to time in order to move the more freely in search of food. These occasions provide the parasite with her opportunity for attack. She settles on the ground near the unsuspecting cutworm and runs rapidly forward until she is within striking distance of it. Then, bending forward her abdomen till it projects between her front legs, she poises for an instant, with wings and antennae vibrating rapidly, as though she is carefully selecting the exact spot in which to commit her offspring to its life of imprisonment in the body of the cutworm. The spot selected, she lunges forward and places her egg deeply among the tissues which will provide the resulting grub with its future nourishment. Immediately the head of the cutworm whips around to the attacked spot. Its wide-open jaws, however, snap on empty air for, quick as the counter-attack has been, the parasite is quicker, and is already on the wing in search of a further victim.

For several weeks the attacked cutworm, in so far as its external appearances are concerned, remains perfectly healthy and is normal in its behavior. Within its body, however, is a rapidly growing grub, which most carefully selects a diet of tissues that are non-vital to the existence of its host. At last this grub is mature and is almost ready to turn into the pupal stage in which it will pass the winter. Before so doing it has three important duties to perform. First of all it takes the largest meal of its life. No longer need it spare the life of its host which has yielded, up till the present time, its daily ration of fresh meat. Such delicacies as the heart and the nervous system, which have in the past been

most scrupulously avoided, are consumed in this final gorge.

This accomplished, the grub now gnaws its way through the body-wall of its fast-dying host and, as a final preparation for its long winter rest, it spins around itself a delicate cocoon of silk. Early in the spring it matures into an adult, winged, ichneumonid and this story is repeated at the expense of the next year's cutworms.

From this brief account it is at once clear that every time the parasite is successful in laying an egg in a cutworm, provided no other factor would have destroyed either of them, there will be one less moth in the fall and one additional parasitic ichneumonid in the spring. It is this fact that determines the annual abundance of both host and parasite. Their relative abundance is, however, subject to slight, or at times to very great, variations as a result of the other factors that we mentioned earlier, particularly that of the direct effect of climate. A heavy storm, or a prolonged drought, may be detrimental to the population of either the host or the parasite. On the other hand, unusual climatic conditions may be very favorable to the one without appreciably affecting the welfare of the other.

Let us suppose that, for some such reason, parasites are unusually abundant in a given year. They will then parasitize a larger number of the cutworms than is usual. Fewer moths will emerge in the fall, fewer eggs will be laid and there will, therefore, be fewer cutworms in the following spring. The somewhat superabundant ichneumonids of this generation will, in consequence, have greatly reduced opportunities for egg-laying and their families will be below normal. Their numbers, as well as those of the cutworms, are thus automatically reduced. As we shall see later, this condition is favorable to an increase in the population of the cutworms, and they will continue to increase during the next few years until, finally, both their population and that of the parasite is brought back to its normal abundance.

If, on the other hand, owing to climatic disturbances, the numbers of the parasites are reduced in any year this will lead to reduced parasitism of the cutworms. More moths will emerge in the fall, more eggs will be laid and, in the following spring, cutworms will be unusually numerous, while the parasitic population will be below par. Such ichneumonids as there are will, however, be able to find many more cutworms than is usual in which to lay their eggs and each will, in consequence, raise an exceptionally large family. It is more than likely that the percentage of cutworms that are attacked will be below normal, but the actual number of eggs that will be laid, even in this year, may be in excess of normal, provided the ichneumonid population was not too seriously depleted. By the third spring, then, their numbers may already be considerably above normal. Even when the numbers of the parasites have been so seriously depleted that they are unable to overtake their rapidly increasing host in one year it can but be a matter of a few years before they become so abundant, in consequence of the unusual opportunities that are thus offered for reproduction, that any further increase is prevented only by the fact that the host, however numerous it may have become in the meantime, becomes so heavily parasitized that it is well-nigh exterminated. The superabundant parasites of the next generation then find so few opportunities to reproduce their kind that their numbers, as well as those of the host, are reduced to far below normal. The host, as a rule, is very near to extinction in this year but the progeny of those that manage to survive are subjected to an abnormally light parasitism by the greatly depleted parasite population of this generation.

Their numbers, therefore, begin to increase once more, and during the next few years there will be slight fluctuations in the relative numbers of the host and the parasite till both reach their normal abundance, when a stable equilibrium will be once more established.

A feature of this relationship that may not appear to be quite clear is that of the increased percentage of parasitism which occurs when both host and parasite are present in abnormally large numbers and its reduction when, conversely, their numbers are both below normal. The following illustration may throw some light on this point.

Let us suppose that, in a given area (a quarter-section or a garden, whichever you prefer) there are, in a normal state of equilibrium, ten cutworms and one parasite, and that in these numbers the parasite is just able to keep both its own population and that of the cutworm stable from year to year. Now, for some such reason as we have given above, the cutworm population has increased to 100 and, in consequence, the parasite population has already increased to 10. The ratio of 100 : 10 is obviously the same as 10 : 1, and at first glance one might conclude that these insects were again in a state of equilibrium, even though the farmer now had to contend with 100 cutworms where formerly he had but 10.

We must, therefore, look into this matter a little more closely. In years of normal abundance, in our postulated area, each of the cutworms which inhabited it had but one parasite awaiting an opportunity to lay an egg in it. Now, however, each of them has ten of these enemies seeking its destruction. Its chances of successfully avoiding the attention of a parasite are, therefore, greatly reduced. Conversely, the parasite normally had but ten chances of raising a family whereas now, despite the competition of rivals, it has one hundred opportunities at the beginning of the season. We have already seen that any increase in the numbers of the host insect inevitably leads to a corresponding increase in the numbers of its parasites and we now see that this mutual increase must, as inevitably, be to the detriment of the host in the long run. For precisely the same reasons a reduction in the numbers of the host and of the parasites will be advantageous to the increase of the host until such time as both have regained their normal abundance.

We may sum this up by stating that the average annual abundance of any plant-feeding species of insect is dependent mainly upon the ease with which it can be attacked by its parasites. The population of those which are not well adapted to escape attack will, other things being equal, be smaller than that of those which are the better able, whether by habits or structure, to avoid their unwelcome attentions. The relative number of eggs that are laid by different species of insects has surprisingly little effect upon their annual abundance.

In order that we may return, without further delay, to our original topic of the effect of birds on insect populations I must ask you to accept the statement that, provided man does not upset the relationships between any plant-feeding insect and its parasites, the average population of that plant-feeding insect can never vary very extensively over periods of more than a few years. When they are present in their *average* numbers the majority of our plant-feeders are not sufficiently numerous to cause very severe losses. Unfortunately for us, the factors that maintain the balance among many of these are so delicately adjusted that it requires only a very slight climatic disturbance to inaugurate an oscillation from the mean of relative abundance. For several years thereafter the population of the insect in question is not in a state of equilibrium with its parasites. It rises and falls, now above

normal, now below it till, like a swinging pendulum, it comes finally to rest. In the meantime, however, we may have experienced one or more "outbreaks" of the insect that have caused severe losses to those who are most directly concerned with its activities.

This brings us to the point where we can consider the part played by birds in regulating the average population of these insects. Let us suppose that, in the district to which we have already alluded, the 21,000 bushels of insects that are destroyed daily by birds consist entirely of plant-feeders and that, by the end of the season, 50 per cent. of the original cutworm population has found its way into the crops of these birds. Then let us suppose that, by some fell disease or by the hand of man, every bird in the district is killed in a single year. We will grant, for the moment, that there would be twice as many egg-laying moths in the fall, and therefore twice as many cutworms in the following spring. This will be a bad year for the farmers, but it will be a most favorable one for the parasites. With twice the normal opportunities for egg-laying each should produce almost twice as many offspring as was possible in the case of their parents. Their numbers will, therefore, increase accordingly and they will continue to do so in subsequent years till they have once more reduced their host to the normally small numbers that prevailed when birds deprived them of half of their opportunities to raise a family.

All that the sudden cessation of bird activity would do would be to inaugurate an oscillation in the relative abundance of the host and the parasite, such as might be produced in any season by a slight variation in climatic conditions.

The relationship is, indeed, somewhat more complex than it may appear to be at first glance. For the sake of clarity we illustrated the laws of equilibrium between host and parasite on the assumption that only one species of parasite attacked the cutworm. There may, however, be a dozen or more different species of parasites concerned though their interrelationships do not greatly affect the problem in so far as we have, as yet, presented it. Of more importance is the time of the year at which these parasites and the birds, respectively, destroy the insects from which they are all deriving their sustenance. Despite the complexity of the problem it is, however, obvious that when, after the postulated removal of birds from the complex, an equilibrium between the host and its parasites has been reestablished, the former can not be present in appreciably greater numbers than it was originally. If it were so, as we have shown earlier, the parasites would be able to increase steadily from year to year, owing to the unusual opportunities thus afforded for egg-laying. This would inevitably lead to a more excessive parasitism and a corresponding reduction in the numbers of the host. We can not but conclude, therefore, that the annual destruction of plant-feeding insects by birds has no appreciable effect upon their ultimate abundance.

In this brief statement we have made no mention of the direct effect of the birds on the parasites themselves. In normal years it is probable that, by the time the birds capture and destroy the majority of their complement of cutworms, well over half of them are already parasitized. Not one of these would have produced an egg-laying moth, but from it would ultimately have been bred a parasite. Furthermore, a large percentage of the adult parasites have their invaluable activities rudely terminated when they are snapped up, in the early spring, by a hungry bird.

When one takes all these factors into account I think that you will pardon me for disagreeing with those writers who claim that birds play an important part

in holding down the numbers of the majority of our insect pests. I can not but believe, in fact, that in many instances they are more inclined to have somewhat the reverse effect upon their total numbers.

Some doubt regarding the value of birds to the agriculturist has been expressed by various writers, but it has been based almost entirely upon the question of the direct destruction of parasites by birds. It is mainly among Italian writers that this doubt has found expression and it is of some little interest in this connection to note that insectivorous birds are relatively scarce in the Italian fauna.

Rondini, for example, came to the conclusion, some fifty years ago, that "the policing of the fields can not be entrusted to birds because they are unreliable and kill the guilty with the innocent." Opponents to this view have not been backward in bringing forward arguments to counteract his conclusions. They show that many of the parasitic insects that are found in the stomachs of birds may be parasites of parasites (*i.e.*, hyperparasites) of injurious insects and are therefore themselves injurious, or they may be parasites of beneficial insects that destroy weeds, etc. These arguments appear to me to be a little forced. Even if we agree, however, that the direct destruction of parasitic insects by birds has an inconsiderable effect upon the population of noxious insects, this does not place them upon a firm foundation as guardians of the farmers' pocket-book from steady depletion through the agency of an ever-increasing horde of hungry insects. This is a matter of minor importance compared with the inability of these same birds to reduce the ultimate population of harmful insects by feeding directly upon them.

There is, however, another side to this story which is very much in favor of the birds in their rôle of reducing losses by insects. Even though the parasites, if left to their own devices, will hold plant-feeding insects to approximately the same numbers from year to year as they do with the assistance of birds, the majority of them have a far less satisfactory way of so doing from our point of view.

Though of some hundred cutworms they manage to lay eggs in ninety individuals and thus assure the ultimate destruction of all but ten, every one of these hundred cutworms will continue to feed till the end of the season. Supposing, however, that birds were present in sufficient numbers to have destroyed fifty of these cutworms. Many species of birds, even though later in the summer they may turn their attention largely to a vegetable diet, feed their nestlings during the spring almost entirely on insect food. It is at *this* season that the farmer most desires a friend who will reduce his insect pests. Here the bird scores heavily over his rival parasites. Every time he places a cutworm on his bill of fare that cutworm ceases forthwith to take his daily ration of the farmer's crops. Even though he may somewhat hamper the parasites in their invaluable rôle of keeping the plant-feeders to a constant numerical inferiority, he has the happy knack of killing his victims in the early stages of their meal instead of at the end of it. This is no small item to be placed to the credit of the birds.

On somewhat rare occasions, also, birds may perform a valuable service in nipping an incipient insect outbreak in the bud. The majority of plant-feeding insects, as we have stated, are attacked by a variety of parasites, each of which has a different life-cycle from its associates. Adverse climatic conditions may severely reduce the numbers of one or more of them though it does not often happen that all will be similarly affected. At such times the more fortunate species are not slow to take advantage of the situation and they

enjoy a temporary increase in numbers, to the corresponding detriment of their host. They will continue so to do till their erstwhile rivals have recovered from their temporary eclipse and are in a position once more to oust them from their position of vantage.

Occasionally, in localized areas, conditions may have been such that all the parasite complex is below par in point of numbers and the host increases accordingly. This unwonted abundance of food in a limited area frequently leads to the foregathering of an unusual number of birds, which rapidly reduce the ravaging insect hordes to negligible numbers. Such conditions are not uncommon in orchards. Many of the insects that infest fruit trees are too numerous, even when present in their normal numbers, for the prosperity of the grower. He seeks, therefore, at a considerable expense to himself, to keep them to a constant numerical inferiority by the annual application of poisons, etc. By so doing, he inavoidably reduces the parasite population to an extent that renders them incapable of restoring equilibrium in any year in which his spraying operations have not yielded the full measure of success. Under such conditions it is not surprising that, through some mismanagement, individual orchardists are visited occasionally with serious local outbreaks of some pest that his neighbors have forestalled. As a result of this, however, his orchard may become the recognized "dining-hall" for numerous birds, which remain in it till they have exhausted this local abundance of food and, incidentally, have performed a valuable service for its owner. A similar example is that of the widely advertised feast of the Franklin gull upon the localized outbreak of the Mormon cricket during the early days of agriculture in the state of Utah.

We must, however, be on our guard against accepting the sweeping generalizations which some writers deduce from these somewhat unusual instances.

Consider for a moment a wide-spread outbreak, such as that of grasshoppers over thousands of square miles of prairie. Normally, shall we say, the birds destroy some 10 per cent. of the somewhat sparse population of grasshoppers that inhabits this territory. The latter have, for a period of a few years, succeeded in shaking off the attentions of their parasites to a large extent, and their numbers have increased a thousandfold. Greatly as many birds in this area enjoy a diet of grasshoppers they obtain almost as many as they desire in years of normal abundance. Is it reasonable to suppose that they will continue to destroy 10 per cent. of them now that there are a thousand where normally there was but one? The total population of insect-feeding birds does not rapidly increase as the result of an outbreak of any particular insect, as is the case with parasites. The *percentage* of any insect that will be destroyed by birds therefore inevitably drops below normal in times of wide-spread outbreaks, and they fail signally to play an effective part in the all-essential problem of restoring equilibrium.

In the foregoing remarks I have confined my attention to the general relationship between birds and plant-feeding insects in an effort to offset similar generalized statements, such as those to which I have referred. Though I have selected one insect, the cutworm, as an example the principles outlined can be applied with equal force to the vast majority of plant-feeding insects, such as grasshoppers, tent caterpillars, cabbage butterflies, etc. There may, however, be a number of exceptions to these rules. These occur principally among

insects of foreign origin, that have been accidentally imported into this country. Frequently their natural enemies have not been brought over from their native land with them. So delicately adjusted are the relationships between the majority of parasites and their insect hosts that, in many cases, no parasite, that is native to this country, can turn its activities to the exploitation of an invader. It also happens that the parasites of some of these imported insects, even if they are brought to this country, are unable for a variety of reasons to become acclimated to conditions that exist here. The normal regulative factors which hold these insects to innocuous numbers in their native land may therefore cease to operate in the new land of their adoption, with the result that they may soon prove disastrous to the grower on whose produce they subsist. Birds which feed on this type of insect are of considerable value in the services they render in reducing the human effort that is necessary to keep their numbers in check.

It is possible that a few native insects should be included in this category. Wireworms, for example, are rarely, if ever, held in check by parasitic insects. Certain cultural operations may so reduce the effectiveness of the other natural factors that normally destroy their surplus population that their consequent increase in numbers frequently proves very detrimental to agriculturalists. These cultural operations, however, afford increased opportunities to birds to destroy wireworms by bringing them to the surface and this, in all probability, goes a long way towards counteracting their otherwise harmful effects.

Such cases are, however, exceptional and it is improbable that, in the case of the vast majority of plant-feeding insects, birds are a factor of much importance in reducing their population.

GRAZING AND FORESTS

By Dr. CHARLES WENDELL TOWNSEND

IPSWICH, MASSACHUSETTS

THAT fire or the cutting tools of man are destructive to forests is evident, but to affirm that the gentle sheep and cow, or even the belligerent goat and rooting pig are the most thorough-going destroyers of forests seems at first sight to be a rash and improbable statement. A little study and reflection will, however, show that this is the case, and some recent travels in Palestine, Syria, Greece and England, where grazing has been practiced for centuries, has brought this subject very strongly to my attention.

Charles Darwin in his "Voyage of the Beagle" shows very clearly that domestic animals introduced in the island of St. Helena have destroyed the forests there. He was struck by the grass pastures, the hedgerows and the plantations of imported trees, in other words by "the English or rather Welsh character of the scenery." Two plains containing no less than two thousand acres "in former times were covered with wood, and were therefore called 'The Great Wood.' So late as the year 1716 there were many trees, but in 1724 the old trees had mostly fallen; and as goats and hogs had been suffered to range about, all the young trees had been killed." He adds: "It is also said that in 1709 there were quantities of dead trees in Sandy Bay; this place is now [1836] so utterly desert, that nothing but so well attested an account could have made me believe that they could ever have grown there. *The fact that the goats and hogs destroyed all the young trees as they sprang up, and that in the course of time the old ones, which were safe from their attacks, perished from age, seems clearly to be made out.*" The italics are mine. It is a simple and clear explanation of the manner of destruction of forests by domestic animals. Darwin also says: "It is very interesting thus to find, that the arrival of animals at St. Helena in 1501, did not change the whole aspect of the island, until a period of two hundred and twenty years had elapsed."

This very slowness of the process serves to mask its destructive character. The life of man is comparatively short and he sees the forest trees unharmed by the animals, so he is loath to believe that they are factors in deforested regions. If he could revisit the forested plains and mountains, where grazing is permitted, two hundred years later, like Darwin he would be surprised to find the whole aspect of the scene changed to grassy pastures. Not only this, but he would find many steep places, now thickly forested, entirely barren, for a forest can maintain a steeper angle for growth than can grass, and, in the absence of trees, the soil washes away leaving only the rocks. Then, too, the forest floor, the accumulation of centuries, of fallen leaves, branches and tree trunks, all mellowed by decay and its organisms into a rich loam, becomes depleted in a pasture and comparatively sterile, for the grass is cropped short by the cattle and does not remain to enrich and build up the soil. It is true there is a certain amount of enrichment

by the droppings of the animals, but the value of this is often lost by desiccation, and, in the east, much is used for fuel.

Not only in St. Helena, but in numerous other countries where herds and flocks are pastured, are these effects evident. In Palestine and Syria and Greece, wherever grazing has been carried on for centuries, the land is generally desolate. It is true that the rainfall in many places is too scanty to support a forest growth, but one may see in other places, as in parts of Palestine, successful attempts at reforestation, fenced off from the destroying sheep, surrounded by stony pastures of thin soil.

In England and Scotland, however, where the rainfall is plentiful and where the land is not above tree level, this subject is abundantly illustrated. Here, as in St. Helena, there are regions called "Forests," and so designated on the maps, where over large areas not a tree is to be seen. Exmoor Forest and Dartmoor Forest are striking examples. Previous to 1337, Dartmoor Forest had been granted to Richard, Earl of Cornwall, by Henry III, while Exmoor is mentioned as a royal forest in a charter of King John. These were extensive forests in those days. Besides sheep and cattle and hogs, which have been pastured there for centuries, wild ponies and red deer were and still are, in places, abundant.

It may be said, by way of parenthesis, that wild deer, living under natural checks of wolf, cougar or savage, probably never increase to such an extent as to endanger the forests, but, when these natural checks have been removed by so-called civilized man, as, for example, in the Kaibab Forest, deer increase so that the eventual destruction of the forest is likely.

Gilbert White, in his "Natural History of Selborne," says of the neighboring royal forest of Wolmer, a tract of land of about seven miles in length by two and a half in width, that it "consists entirely of sand covered with heath and fern; but is somewhat diversified with hills and dales, without having one standing tree in the whole extent." He states he has "seen cottages on the verge of this wild district, whose timbers consisted of a black hard wood, looking like oak, which the owners assured me they procured from the bogs by probing the soil with spits." He unwittingly explains this "forest without a standing tree" by speaking of the great herd of red deer kept there which, even at the beginning of the eighteenth century, amounted to five hundred head. And he says further: "The manor farm of the parish of Greatham has an admitted claim, I see (by an old record taken from the Tower of London), of turning all live stock on the forest, at proper seasons, *bidentibus exceptis*. The reason, I presume, why sheep are excluded is, because, being such close grazers, they would pick out all the finest grasses, and hinder the deer from thriving."

The scenery about the English Lakes is beautiful and romantic. In many places there are fine trees, but the hills and mountains, whose height never reaches above tree level, are for the greater part treeless. Ancient stone walls, stretching even over the tops of the mountains, indicate the use of these lands for pastures. On Mt. Helvellyn I found sheep grazing on the grassy slopes, but that these same slopes could support trees was apparent, for, in a fenced-in portion, a small planted forest was flourishing. Where trees are planted thickly together, they flourish, even in wind-swept regions where individual trees would perish. That all these regions were formerly densely forested, even on many steep slopes now rocky and devoid of soil, is highly

probable, and that the deforestation came about partly by the axe and fire of man, but chiefly by the slow and insidious, century-long process of browsing animals is clear.

Many of these grassy pastures in England are now so far removed from any trees and shrubs whose seeds would replant them that, even if the cattle were taken away, it would be long before trees and shrubs would spring up. Not so in other regions, as here in New England. "One can easily discover by a simple experiment that in as short a time as ten years a sod-covered upland will return to an incipient forested condition, provided three destroyers—fire, the cutting tools of man, and the teeth of browsing cattle are excluded. Wild roses and blackberry brambles spring up in the grass, and bayberries, hardhack and barberries soon follow. The more cover these give for the birds to nest and roost in, the more seeds are dropped there by these natural forest planters, and sumacks, thorns, rum cherries, apples, maples and red cedars soon appear."[1]

In the dark spruce forests of southern Labrador I have seen extensive light green patches of white birch, indicating a spot where fire had swept through the spruce forest and where the ground had been reseeded by wind-blown birch seeds.

For how many thousand years countless buffaloes roamed the Great Plains we do not know, but one can conjecture that in those parts where the rainfall is sufficient, forests would have prevailed but for them.

We must see to it that our existing national forests do not become grassy and barren wastes by the insidious action over a long period of time of the gentle sheep.

[1] Charles Wendell Townsend, "Sand Dunes and Salt Marshes," pp. 226, 227.

AMERICA'S INFLUENCE ON THE DEVELOPMENT OF THE SCIENCES

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We Americans have been told time and again by visitors from across the Atlantic that although undoubtedly a great business people we are superficial and materialistic, and that our scholarly attainments are as child's prattle compared with the mature achievements of Europeans. We are merely a practical nation, they say, holding the dollar so close to the eye that we seldom see around it. We have our Edisons, our Bells and our Wright brothers, who apply the results of scientific advance to the practical arts, but Galileos and Newtons are not found among us.

Most Americans have taken it for granted that these criticisms are justly made. We have, in fact, seldom examined carefully into them. It is surprising, therefore, to find that far from contributing little to fundamentals in scientific advance, America stands today in the very forefront with three other nations and that compared, for example, with Italy, the home of Galileo, our country in the past century has produced at least ten times as many great scientists.

Even in early colonial times we made our influence on science conspicuously felt. Two hundred years ago, when modern science was very young the world over, there loomed upon the horizon an American lad who was destined to become not only one of the founders of the Republic, but one of the greatest of scientists.

But before taking up in any detail the influence of America upon the development of science, let us for a moment examine the conditions in this and other countries when the United States was in her infancy, two hundred years ago. Europe was then in the midst of the scientific Renaissance; England had passed through her political revolution; most of the other European nations had become established, and for several centuries a deepening literary and scholastic tradition had been taking root on the other side. Facilities for research were already extensive over there. European universities had been functioning for over five hundred years.

Yet with all this tradition and preparation what had Europe accomplished by 1727? How many great men of science had half a millennium produced? The answer is instructive. From Roger Bacon's day in the thirteenth century to Newton's in the early eighteenth (the latter died just 200 years ago), hardly more than twenty illustrious names sum up European achievement in all departments of science, eight Englishmen, four Italians, three Germans, one Hollander, one Pole, one Belgian, one Frenchman and one Dane standing forth conspicuously. And if we limit ourselves to mathematics, theoretical astronomy and mechanics, which in the five hundred years here under consideration were the only departments of science that had been placed upon a secure footing, half that number of great names comprehend the accomplishment. In the physical sciences, an average of two outstanding contributors per century was all Europe had been able to produce up to 1727. As for chemistry, geology, biology and psychology, they were then hardly more than convenient

labels for separate groupings of unsolved problems. In these fields not even a clearing away of grotesque misconceptions had been achieved. For the most part, even the labels were unintelligible at that time.

Europe had passed through more than half a millennium of scholarly tradition and activity. In America but a century had elapsed since the landing of a handful of Pilgrim pioneers in New England. A small oasis of civilization had taken form in the midst of savagery; but the hostile Indian and the untamed wilderness were still enormous hazards and it was all the sturdy colonist could do to keep the wolf and the tomahawk from the door. I do not suppose there is any one, even among America's most bitter critics, who holds it against her that during this early colonial period of hardship and misery no great scientist arose from her scanty population. One would hardly expect that up to the Revolution or even until after the war of 1812, the United States could become secure enough against elemental dangers and established enough in a scholarly tradition to produce even one conspicuous physical scientist in the face of Europe's meager accomplishment in over five hundred years; and yet in the eighteenth century this youngest and poorest equipped of the nations produced two of the world's greatest physicists—Benjamin Franklin and Count Rumford—besides several other physical scientists worthy of mention.

Benjamin Franklin (1706–1790) had established himself as an educator, successful newspaper man and literary writer in Philadelphia, where among other things he founded the *Saturday Evening Post* and the academy which later developed into the University of Pennsylvania, when at the age of forty he became interested in frictional electricity and began the experiments which were to place him among the illustrious men of science. In 1747 he put forth his famous "one-fluid" theory, which was quickly accepted throughout the scientific world and which has been held until very recent times. It is, in fact, at present experiencing a revival. The theory states that all bodies possess electricity but show no signs of it unless by some means they receive a surplusage, when they may be said to be "positively charged," or lose some of their normal portion to other bodies, when they may be said to be "negatively charged." This simple explanation has sufficed even to this day to elucidate all ordinary static electrical phenomena.

Following the enunciation of this theory, Franklin turned his attention to the meaning of lightning. In experimenting with the Leyden jar, which had been invented not long before for the purpose of collecting and intensifying electrification by friction, he had made use of pointed rods for "drawing off and throwing off the electrical fire," as he expressed it, and he had noticed the remarkable resemblance between the Leyden jar discharges thus affected and the phenomenon of lightning. He therefore determined upon his celebrated kite experiment to see if he could draw down the lightning along a silken string attached to the kite. His success in this daring and startling adventure is common knowledge. It gained him universal recognition, won him honorary doctor's degrees from leading English universities (Oxford, Edinborough and St. Andrews), his election as a fellow of the Royal Society, and the award by England of the famous Copley Gold Medal. In that day no higher recognition could have come to any scientist.

Count Rumford (1753–1814), born under the name of Benjamin Thompson in Woburn, Massachusetts, was eminent not only as a man of science, but also as exemplifying in a very practical way the brotherhood of all men. Virtually forced into the ranks of the Royalists

during the Revolutionary period because of the jealousy of fellow officers in the colonial militia, who resented a mere lad being placed in a position of superior command over them, he left for Europe after receiving his scientific training here, and rose rapidly to prominence in the scientific, social, military and political life of three nations. In England, he became under secretary of state, founded the Royal Institution of London and was elevated to the knighthood; in Bavaria, he was created Count Rumford, served as privy councilor, chief of police, and minister of war, and so revolutionized social conditions in the city of Munich that, although a foreigner and a Protestant in a community predominantly Catholic, the poor of the city spontaneously turned out *en masse* to offer up public prayers for his recovery during a serious illness. In France he married the widow of the distinguished French chemist Lavoisier and became a close friend of Napoleon, Lagrange and Cuvier. By this time the Czar of Russia was urging him to make his home in St. Petersburg and President Adams was offering him the positions of superintendent of the American Military Academy and inspector general of the artillery of the United States. Rumford never lost his love for his native land, despite the jealousies that had driven him from her shores. He left his fortune to Harvard, where under privation and difficulty he had received his training in science.

It would seem that such an active career as Count Rumford's would leave little room for scientific pursuits. And yet his whole mature activity represented a colossal experiment in science. Whether in his project, which never materialized, to survey the White Mountains in this country, or in his work in European armies where he experimented upon the action of gunpowder and projectiles and the nature of heat, or in his introduction of improved methods of horse breeding or in his social experiments of one kind and another, every new experience seemed to present to him an additional opportunity for research and experimentation. The whole world was Rumford's laboratory.

His claim to recognition as a distinguished man of science centered about his investigations into the nature of heat and his attack upon the theory of imponderables, which latter comprehended certain figments of the imagination manufactured to explain well-known physical phenomena. There was the so-called "corpuscle," thought to have something to do with the propagation of light; "caloric," which a body was presumed to draw into itself when heated and lose when cooled; "phlogiston," which a substance was supposed to give off when burning; and "effluvia" which was thought to have something to do with the behavior of electricity. Various fantastic suppositions as to the properties of "caloric" and "phlogiston" had been put forth until the whole subject of heat was almost hopelessly entangled. Heat was generally regarded as a tangible substance, and so was fire.

It was towards the close of the eighteenth century that Count Rumford began to suspect that heat has no material existence, and in 1798 while engaged in boring cannon at a military workshop, he decided to put the caloric theory to a test. His convincing experiments we can not go into here. We can only state his conclusion, which was that heat is a form of motion, caused by the friction of one body against another, and that caloric is a meaningless and gratuitous assumption. By this time the chemists had demonstrated that phlogiston is likewise meaningless. Rumford felt persuaded that he would live to see "caloric interred with phlogiston in the same tomb." His conclusive experiments and a strong attack upon the imponderable theory by another noted

scientist at about the same time, should have been sufficient to mark the obsequies of caloric. It was not until the middle of the nineteenth century, however, that the interment which Rumford expected to witness, actually took place.

The accomplishments of these two native-born Americans were of preeminent importance for further advances in physics. In Franklin's day the phenomena of electricity were still very largely misunderstood. Weird beliefs (such as that goat's blood, garlic, melancholy and seduction influenced or were influenced by magnetic attraction!) were held with respect to electrical and magnetic causes and effects, and current electricity was unknown. Franklin's brilliant experiments and clarifying hypotheses laid the foundation for the remarkable developments which began soon afterwards. . . . On the side of a better understanding of various manifestations of energy, nothing could be accomplished so long as the imponderables continued to raise barriers between heat, light, electricity and magnetism. Count Rumford's experimental proof that caloric is a gratuitous assumption and that heat is a mode of motion led the way to the discrediting of other imponderables, to the reduction of all forms of energy to modes of motion in a circumambient medium, and to a focusing of attention upon the nature of the ether and the source of motion in the structure of the atom. Space will not permit our reviewing in this article the work of other prominent American scientists of the colonial period, notably that of John Winthrop, of Harvard, friend of Franklin and teacher of Rumford, and of David Rittenhouse, of Philadelphia, who was a widely-known astronomer of the time: We must pass on to other developments.

It must not be thought that while America was producing at least four brilliant physical scientists in her first century of scholarly activity, European nations were accomplishing nothing in their sixth. In fact during the same seventy-five years (from around 1727 to the end of the century), France produced eight distinguished physical scientists, Great Britain five, Italy and Switzerland two each, and Holland one. In addition, geology and biology saw considerable preliminary advance, although these had not yet become in any true measure sciences. The outstanding accomplishment of Europe in the eighteenth century was the establishment of chemistry at the hands of several noted Englishmen and the great Frenchman Lavoisier, who was beheaded during the French Revolution, because in a democracy, it was maintained, there is no need for learned men. *La République n'a pas besoin des savants!* Such a conception appears grotesque to us, and yet it is surprising how widespread it is among certain classes even to-day. . . .

The nineteenth century saw an unprecedented development in all scientific departments. When it opened, mathematics, astronomy, physics and chemistry were fairly well established. Before it closed, the practical applications of these sciences had literally transformed the material environment of man, and three new sciences—geology, biology and psychology—had reached their majority, though the claim of psychology to be called a science, even to-day, may still in some respects be legitimately questioned. In visualizing the development of science it should be remembered that from mathematics to psychology a very definite hierarchy is disclosed. The scientific structure may well be likened to a building several stories high, mathematics constituting the foundation, physics the first floor, chemistry the second, modern astronomy the third, and geology, biology and psychology the fourth, fifth and sixth, respectively. It was not until the last century that the lower stories were com-

plete enough for the rest to be put into place.

In all the unprecedented scientific advance of the nineteenth century, the United States has played an important part, not only in practical applications to art and industry in which she may well be considered preeminent, but also in establishing the fundamental principles without which the applications would be impossible. In Josiah Willard Gibbs, of Yale, she produced a man who might rightly be designated the Newton of chemistry, and in other respects she has actually been in the vanguard of the forward movement.

A comparison of the achievements of American scientists in their second century of scholarly activity with Europeans in their seventh, reveals an interesting situation. There is, of course, legitimate room for difference of opinion as to what scientists should be considered great and who are near great at the present time, but a rough measure of nineteenth century accomplishment can be secured on which most authorities will agree. In European scientific achievement, Italy declined, Holland and Switzerland remained about stationary, Scandinavia and Russia advanced, but none of these nations yielded more than six scientists of note in the past century. Great Britain, France and Germany, however, each produced more than thirty men of outstanding excellence, and so did America. The most phenomenal advance here has been in Germany with the United States second, although it must be remembered that both Great Britain and France had a larger representation of scientists at the beginning of the nineteenth century and that their absolute contributions in the succeeding hundred years have been close behind those of Germany. At any rate, these four nations stand in a class by themselves in respect to modern scientific accomplishment.

Let us turn now to a somewhat more detailed examination of America's recent contribution. In the physical sciences we have mentioned Josiah Willard Gibbs (1839–1903) who was conspicuous as a mathematician, physicist and chemist. Gibbs was born at New Haven and was graduated from Yale, subsequently engaging in advanced study in France and Germany, and returning to the United States to occupy the chair of mathematical physics at his alma mater, where he remained for the rest of his life. Two notable books resulted from his endeavors; one entitled "The Equilibrium of Heterogeneous Substances" and the other "An Elementary Treatise on Statistical Mechanics." He contributed also to the subject of vector analysis, and applied the results to crystallography, to the theory of light and to the closer computation of the movements of heavenly bodies.

Gibbs's monumental work on statistical mechanics and chemical equilibrium saw publication between 1875 and 1880. By that time the young science of chemistry had experienced a considerable advance, especially in the isolation of elements, the determination of their atomic weights, the establishment of the meaning of atoms, molecules, valences, radicles and chemical formulae, and in the phenomenal rise of organic chemistry. Two Englishmen, two Germans, an Italian and a Russian played the important parts here—Davy, Dalton, Wöhler, Liebig, Avogadro and Mendeleeff. But the effects of pressure, temperature, light, electricity and motion upon chemical change—effects of much greater import for chemistry than the developments just mentioned—could hardly be ascertained until the physical processes were themselves clearly understood, and organic chemistry, despite its rapid development, deals, in the main, with only four elements out of ninety.

General or inorganic chemistry had

remained undeveloped, both because the organic branch took most of the workers and because the basis for a further advance was not provided until after the middle of the nineteenth century, when the conservation of energy and the electro-magnetic theories were enunciated and established through the efforts of a brilliant group of Englishmen and Germans—Joule, Kelvin, Mayer, Helmholtz, Faraday and Maxwell most prominent among them. Building upon these physical principles, Josiah Willard Gibbs, with his penetrating insight into the mathematics and physics of chemical processes, cleared away the obscurities and perplexities hampering progress in general chemistry, and laid the foundations for further constructive advance. The colossal accomplishments of this Newton of chemistry are only now coming to be fully appreciated, although Gibbs's work was recognized abroad before it was recognized at home. For quite a period his publications were inaccessible here, whereas German and French translations were in extensive use across the Atlantic.

It has just been indicated that a small group of Germans and Englishmen played the dominant rôles in the advances of physics and chemistry in the first half of the nineteenth century. America still played a lesser part here, albeit the impetus in England followed in large measure the work of Rumford, and Joseph Henry (1797–1878), a native of New York, was a worthy American representative of the New World's contribution at the time. Henry was prominent in mathematics and physics. He was an outstanding experimentalist in the field of electricity, inventor of a number of important electrical devices, and the formulator of the principles upon which Morse later perfected the mechanism of telegraphy. The adoption by the International Electrical Convention of the henry, along with the ampere, the volt, the ohm and the farad bears ample witness to the place this nineteenth century American occupies in the world of physics to-day.

In the past seventy-five years American influence in the physical sciences has been increasingly felt. Along with the work of Gibbs in chemistry should be mentioned that of H. A. Rowland (1848–1901), who made notable improvements in spectroscopic method, enabling the chemist through the use of his concave reflecting grating to penetrate more deeply into the structure of the atom, and who contributed extensively to the study of heat, electricity and magnetism. Richards of Harvard, recent Nobel prize winner for his exhaustive researches into atomic weights, symbolizes the character of American contributions in the present day to fundamentals in chemical science.

At the same time that the principles of general chemistry were being enunciated by Gibbs and that investigations into the secrets of atomic structure were being attempted both here and abroad, a determined effort was made to understand the nature of the ether. It was the startling results of the interferometer experiments of two American physicists, Michelson and Morley, which led to an almost complete overturn of established ideas in physics and to the revolutionary hypotheses of Einstein. Equally important have been other American contributions to physical advance in recent years, as, for example, Professor Millikan's measurement of the electron. Second only to the brilliant discoveries by Europeans of X-rays, radio-activity and the electron, and the launching of the theories of Einstein and Planck, stands the work of American physicists at the present time.

In astronomy, the United States today easily outdistances other nations both in respect to the number of her noteworthy contributors, and in the nature of her astronomical equipment. Than Rutherford, Pickering, Abbe, New-

comb and Hill there are no more important recent astronomers anywhere. Rutherford (1816–1892) was the first to construct a photographic refractor and to apply the methods of photography to the determination of stellar positions. Pickering (1846–1919) elaborated upon Rutherford's work and discovered the first spectroscopic system of binary stars. To-day photographic and spectroscopic methods of stellar research are of prime importance everywhere. Abbe (1838–1916) perfected the weather forecasting service for the United States Government, and his methods were later copied all over the world. Through the subsequent work of the Smithsonian Institution, America is now foremost in the field of weather forecasting. The most recent development here is the establishment of an observing station on Mt. Brukkaros in South Africa, which will be linked by radio with two other American stations (one in South America and the other in California) and will provide still more accurate and comprehensive weather statistics. Newcomb (1835–1909) and Hill (1838–1914) were distinguished mathematical astronomers. Both received world-wide recognition. They applied the Newtonian formulae to troublesome problems of celestial mechanics, especially to the movements of the moon and the outer planets. Hill ranks with Laplace in devising helpful equations for the study of three bodies acting simultaneously on one another in space. In the United States to-day there are many able successors to these men. To repeat, the contributions of Americans to astronomy in the first quarter of the twentieth century outrank by far those of any other nation. We have the equipment and the men to maintain this preeminence. The three greatest observatories in the world are situated here—the Yerkes Observatory of the University of Chicago at Williams Bay, Wisconsin, the Carnegie Institution's Observatory on Mt. Wilson, California, and the Lick Observatory on Mount Hamilton, California.

First place must now also be accorded to America in geology, which came to scientific maturity in the past century. The United States shares with England the honor of establishing this science, each nation developing two geologists of highest eminence—Lyell and William Smith on the other side; Dana and Agassiz over here. Agassiz (1807–1873) was not born in this country, but he made it his own, and did the major portion of his work while professor at Harvard. His discovery of the significance of glacial erosion and drift marked a turning point in geological advance. To Dana (1813–1895), a native American, the world owes the modern hypothesis of mountain and valley formation. His text-book, published in 1863, went through a number of editions, and marked another turning point in geological progress. Together with Lyell and Smith, Agassiz and Dana swept aside medieval conceptions in geology—the deluge, catastrophic change, and cold earth theories—and established the principles of uniformitarianism and orderly development which made possible a real science of the earth.

Preceding these eminent men, two other American geologists deserve mention. Silliman (1779–1864) was one of them. He began his work as professor of chemistry, geology and mineralogy at Yale in 1802, in which fields he stands as a pioneer in this country. In 1818 he founded *The American Journal of Science* and was its editor for twenty years. He had a wide appeal as writer and lecturer, and did more than any one else in the United States to bring the then embryo science of geology to the attention of serious students. He was "probably the most influential representative of science in America during the first half of the nineteenth century." Hitchcock of Amherst (1793–1864) was the other pioneer in American geology.

His books written in 1823, 1848, 1851 and 1853 were extensively read.

Following Dana and Agassiz, an increasing number of American geologists have notably influenced geological advance, conspicuous among them being Newberry (1822–1892), Powell (1834–1902), Gilbert (1843–1918), and Dutton (1841–1912) in recent years and Chamberlin, Davis and Daly at the present time. To Dutton the world owes the establishment of the concept of isostasy, which has apparently solved the problem of the cause of continental elevations as contrasted with ocean-floor depressions. Chamberlin has brought forth the planetesimal hypothesis to explain the origin of the earth. Daly is giving weight in this country to the new theory of gradually separating continents recently enunciated by Wegener in Germany; the theory appears to be of considerable importance. An increasing army of American investigators are exploring the earth's surface to excellent effect; and the greatest geological experimental station in the world is the Carnegie Geophysical Laboratory at Washington, where a corps of scientists are constantly at work investigating the deeper problems of the origin of rocks.

America contributed little of outstanding importance to biology during the first six decades of the century. She had neither the laboratory equipment nor the trained specialists in this field, although she did possess lovers of nature like Audubon (1780–1851), who studied the bird and animal life of the American wilderness and preserved it for science in their faithful drawings and descriptions, and like Baird (1823–1887), and later Goode (1851–1896), whose scientific vision and organizing ability did so much to make possible the twentieth century resources of the Smithsonian Institution, the National Museum and the now world-renowned biological laboratory at Woods Hole.

After the publication of the "Origin of Species," America moved rapidly to the fore in biology as elsewhere. Among the half-dozen professional biologists the world over who had the courage, the insight and the strength of conviction to come out flat-footedly for Darwin's hypothesis, was Asa Gray in America (1810–1888). Allying himself with Huxley and Hooker in England and Haeckel and Weismann in Germany, Gray at Harvard cleared the atmosphere of biological misconceptions in the eastern section of the United States and stimulated able students to further investigation. He also became noted for his work in the classification and description of botanical specimens.

At the same time and a little later, the Great Plains of the United States, in Wyoming, Nebraska and neighboring regions, were being explored for fossil remains by three American zoologists and paleontologists who were soon to receive world-wide recognition for their important researches, especially in tracing the ancestry of the horse and the camel, both of which are now confidently held to have originated in this country, the ancestors of the horse some five million years ago. These men were Leidy (1823–1891), Marsh (1831–1899), and Cope (1840–1897). In addition, Marsh discovered some four hundred new specimens of vertebrates, and Cope's work was so extensive and exhaustive that he was ranked first among international paleontologists at the end of the last century. To-day there is no nation which can match the United States in this biological department. Wherever there are extensive expeditions to discover more about life in the past—in the Gobi desert in Asia, in the tombs of the kings of Egypt, or in tracing the ancient civilizations of South America—able Americans are the guiding spirits. Nor need we stop with paleontology and allied subjects. In every biological department America has its outstanding representatives. Than

Morgan, Wilson, Jennings, Wheeler, Osborn and the late Jacques Loeb, there are no more important present-day contributors in their respective biological specialties anywhere. In laboratory and other resources and in preeminent ability, America now stands in the forefront of biological advance.

In the last of the fields of science to reach maturity or near maturity in the past seventy-five years, namely, in that of psychology, the United States has likewise played an important rôle. In fact she produced the world's greatest psychologist, the much-beloved William James (1842–1910). Psychology had been struggling along for centuries encumbered by metaphysical and philosophical prepossessions. Its emancipation began with the discovery of the principles of physiology, with a better understanding of the nervous and glandular systems and the sense organs, and with the rise of the evolutionary hypothesis. Three distinct lines of emancipation can now be traced—that leading in Germany to the establishment of physiological psychology, that leading in France to the rise of hypnotism and psycho-analysis as agencies of diagnosis in the study of mental diseases, and, in England and America, that leading out from the application of the evolutionary conception to a study of animal, savage, child and individual behavior. James brought those streams of activity together in his epoch-making *Principles of Psychology* published in 1890, since which time the center of psychological advance has unquestionably been in the United States.

Nothing has yet been said about sociology, which is to-day endeavoring to organize the various departments of social study (economics, politics, jurisprudence, ethics and the rest) into one consistent whole. Sociology is not yet established as a science. It must await further developments in biology and psychology, especially in the latter. Considerable preliminary work has, however, already been done, the nineteenth century witnessing the appearance of a Frenchman, an Englishman, and an American—the latter, Lester F. Ward, the most important of the triumvirate—who pointed the way for this modern synthesis of the social studies. At the present time a score or more of able Americans are laying the proper foundations for the new science. In this department of inquiry also, no other nation compares with American activity to-day.

A short article covering as broad and unexplored a field as here surveyed must fall considerably short of being completely satisfactory or conclusive. And yet, certain facts regarding America's contributions to the development of science need no elaborate detail to make them clear. Decidedly handicapped because of her late start in building up scholarly traditions and accumulating scientific equipment—she began five hundred years after Europe—the United States has nevertheless developed scientists of the first rank from the Colonial period onward. In the nineteenth century she forged rapidly to the front until she occupied an enviable place close beside Germany, England, and France, each of which, to repeat, produced more than thirty outstanding scientists, over five times as many as any other nation produced in the same period. America's contributions in every scientific field were notable and in some they were preeminent. And as the twentieth century gets under way there is hardly a department in which she is not outdistancing the savants of other countries.

Far from being merely a practical nation, the United States in pure science is only now getting into her proper stride. She has the financial resources, she can readily secure the needed scientific equipment, and she always has had the native ability and intellectual capacity to take the lead in scientific affairs.

The star of her scholarly accomplishment rose comparatively late, but it is quite apparently of first magnitude, and every sign points to its becoming the most brilliant spectacle in the firmament before the second quarter of the new century has passed.

In conclusion, allow me to say that my investigation of the subject-matter of this article has resulted in the conviction that a more exhaustive treatment, under the auspices of some such organization as the History of Science Society in collaboration with the American Association for the Advancement of Science, would be a decidedly worthwhile undertaking, not because of its demonstration of the conspicuous place held by the United States to-day in scientific pursuits as compared with other nations, although this I feel is of undoubted value despite the supposedly odious character of comparisons, but because there is too little understanding among Americans themselves of the significance of scientific research for its own sake.

Men of science everywhere, and this includes the United States, have labored under enormous handicaps. They have too long been regarded as impractical visionaries, whereas as a matter of fact a vast metamorphosis of man's environment has been brought about through their efforts. The industrial revolution, world-wide exploration and colonization, modern machine industry, the myriad creature comforts now brought to the door of the humblest man through the application of the principles of steam, electric, and gasoline power, the rapid rise in the standard of living which has carried with it an enjoyment of the good things of life for every one upon a scale compared with which the splendors of all by-gone ages put together pale into insignificance—all this has come about primarily through advances in pure science. It is quite true that practical America is eternally indebted to the Galileos, the Newtons, the Lavoisiers, the Franklins and the Gibbses in her rapid rise to wealth and power. It is true that she has benefited much by European contributions. But the post-war situation of the world challenges her as never before. She must continue to depend upon pure science for her material welfare. Europe is burdened with debt and frankly admits that she can not be counted upon in scientific research for a long time to come.

Leaders of industry and public affairs in this country must be made to realize their obligations and opportunity. The scholarly ability is unquestionably here. Let those who benefit so enormously through the practical applications of scientific advance in this, the wealthiest nation on earth, see to it that our universities and other centers of research are supplied with adequate funds and equipment. The scientist has been and is doing his full share despite misunderstanding and hardship. The manufacturers and other capitalists of America must properly maintain their goose if they wish to continue to receive an adequate supply of golden eggs. Happily some of them realize that. Whatever can be done to educate the rest will be of enormous benefit to themselves, to humanity, and to further advances in science.

THE BACTERIOLOGICAL WORK OF JOSEPH LISTER

By Professor WILLIAM W. FORD

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WHILE Joseph Lister may be said to have entered surgery through physiology, his knowledge of bacteriology, his active investigations of microorganisms in wounds and his experiments in his private bacteriological laboratory so affected his surgical work as to raise it from the plane of skillful operative technique, equal to that of his contemporaries, to a plane where his observations, deductions and practice revolutionized surgery throughout the world. To comprehend Lister's bacteriological achievements, we must emphasize primarily the influence of his father, Joseph Jackson Lister, a member of the Society of Friends and a successful man of business, who settled about 1827 at West Ham, a suburb of London, and who devoted his abundant leisure for over thirty years to practical work on the construction of the microscope. At that time the best compound microscopes available were quite unsatisfactory, chiefly because the lenses giving higher magnification produced an excessive secondary spectrum, known as a "coma" or "bur" which interfered materially with accurate microscopic vision. In attempts to do away with this secondary spectrum, Lister discovered the law of aplanatic foci and devised a microscope in which the image point of one lens coincided with the focal point of another. For this notable contribution he was made a Fellow of the Royal Society. It is true that in the subsequent development of the microscope the secondary spectrum is gotten rid of by the use of glass with different refractive indices, that is to say the lenses are corrected for chromatic aberration, but nevertheless, Joseph Jackson Lister is credited with laying down the correct principles for the construction of the microscope. As a young boy, Joseph Lister, the second son, and a brother, were highly trained by their father in microscopy and one of Lister's best papers is the one in which he gives the intricate details of his father's researches. Furthermore, when Lister went up to London to study medicine, his father presented him with an excellent microscope with the use of which the young student was thoroughly familiar. Joseph Lister received his academic and medical training in University College, London, where he came especially under the influence of Thomas Graham, professor of chemistry, William Sharpey, professor of physiology and the pioneer experimental physiologist of Great Britain, and John Lindley, the professor of botany. As a youth Lister was a man of powerful physique, an excellent swimmer and a tireless walker. Much of his leisure time while a student was spent in systematic botany, under the tutelage of Professor Lindley, and his collection of Alpine flowers was one of the best in England. For years he followed the work of a talented brother on microscopic fungi, and actually collaborated with him in some investigations although his name does not appear in the title page of the publications. Finally Lister received a thorough training in French

and German sometime during the course of his elementary education so that he read and spoke both languages with considerable facility. Not a bad equipment for a bacteriologist, French and German, chemistry, physiology, systematic botany and microscopy.

After taking his degree in medicine in London and serving as house officer in University College Hospital, Lister, like many other young medical men of England, was drawn to Edinburgh, then possibly the center of medical training in Britain and her colonies. He was provided with a letter of introduction from Professor Sharpey to Dr. James Syme, professor of surgery in the Scotch University and in many ways the leading surgeon of Great Britain. He made a favorable impression on Syme, was appointed his House Surgeon in the Edinburgh Infirmary and soon after married Syme's daughter, Agnes. This latter event is not without significance in Lister's career. Not that the relationship with Syme gave Lister unmerited advancement but that it did give him, while still a very young man, an intimate association with a surgeon of outstanding ability and experience and one, moreover, who was intensely interested in what became Lister's chief interest, namely, the suppurations which followed surgical operations and certain types of injuries. At the time when Lister entered upon his career, corresponding to the decade before the Civil War in this country, from 1850 to 1860, the complications of surgical operations were heartrending. A large percentage of patients upon whom even the simpler operations were performed, died from what, at that time, was called putrefaction of wounds. Healing, when it did occur, was a slow tedious process, accompanied by sloughing and scar formation. Certain types of suppuration were notably common, especially that peculiar condition known as hospital gangrene, which has, incidentally, never been cleared up for us, even by modern methods. All surgeons were deeply concerned about the mortality from operations, and even the boldest shuddered at his results. Like the majority of the surgeons of his day, Lister was worried about the complications of wound healing and talked the matter over frequently with his colleagues. In that era it was generally believed that inflammation was *nervous* in origin and that the putrefaction which took place in the inflamed area was the cause of death. This putrefaction was usually ascribed to the entrance of the gases of the atmosphere, chiefly the oxygen, as a result of which a kind of autolytic break-down of the tissues resulted. With this prevailing theory of the cause of putrefaction in wounds Lister was thoroughly dissatisfied. As a physiologist it did not appeal to him. In a simple fracture, for instance, plenty of oxygen was brought by the blood stream to the contused tissues and yet they did not putrefy. In fractured ribs the lung might be pierced and atmospheric oxygen be present at the site of injury and yet putrefaction did not appear. As a practical surgeon also, the theory did not appeal to Lister. He saw putrefaction develop after slight abrasions of the skin or small punctured openings when the patients were in the hospitals, and large open wounds sometimes heal without suppuration when the patients were in their homes. Over this putrefaction of wounds Lister worried and studied for several years, trying out different types of dressings without success. About 1865, however, a colleague of Lister in the University of Glasgow called his attention to the work of Pasteur on the causes of fermentation and putrefaction which had been published about a year previously. Lister secured the original papers and studied

them thoroughly. Struck by the simplicity of the experimental work, the clarity of description and the soundness of conclusion Lister became an immediate convert to the new doctrine. From this time on we may trace two distinct lines of bacteriological work in Lister's career. He fitted up a private laboratory, perfected himself in the technique of Pasteur and conducted bacteriological investigations over a long period of years. He repeated many of Pasteur's experiments and came to the same conclusions, namely, that fermentation and putrefaction in properly sterilized sugar and protein solutions are always the result of the introduction of bacteria from without, especially from the atmosphere. In the course of this work, Lister employed human urine. After many unsuccessful attempts to obtain and keep it sterile he finally succeeded, by careful attention to the cleaning of his glass ware, and in an introductory lecture delivered in the University of Edinburgh in 1869, he pays high tribute to Pasteur and then describes his own work. At this address he exhibited urine kept free from microorganisms for six months. Similar material he had exposed to the atmosphere and noted in it a rapid decomposition. Some of this decomposed urine had been transferred to sterile urine which in its turn decomposed. Lister did this work in ignorance of similar unpublished work by Pasteur with the same fluid. From this time Lister became the chief advocate of Pasteur's theories, at least as far as the English-speaking world is concerned. As he said, the conclusions of a trained investigator from properly controlled experiments are convincing, while the failure of poorly trained workers to obtain the same results, with improperly controlled technique, may be disregarded.

If Lister had stopped at this point, he would have had an honorable place in the historical development of bacteriology, but little more. His merit lies in his vision. He saw that if Pasteur was right about the causation of fermentation and putrefaction in flasks of nutrient material a similar principle might hold for the putrefaction of the tissues. In just the same way as dust laden with bacteria dropped upon the surface of the fluids, so might bacteria drop on the surface of wounds. Furthermore, if this were the explanation of the putrefaction of wounds, two things were necessary to prevent it. First, the bacteria already in the wound must be killed, and second, a dressing must be applied which was free from organisms and impregnated with substances which would destroy any bacteria which might further be deposited. We have here, it seems to me, one of the most beautiful examples of reasoning by analogy and a striking incident in which a pure hypothesis led to fundamental changes in our entire conceptions. For it must be remembered that at the time Lister studied and confirmed Pasteur's work and applied it to surgery not a particle of convincing evidence had been brought that bacteria are the cause of suppuration and putrefaction in the animal body, and one might even go further and say that no convincing evidence had thus far been presented that bacteria are the cause of disease. For this period in Lister's work may be roughly placed before 1870, six years before Koch proved that the anthrax bacillus is the cause of splenic fever.

Lister immediately began experimental work on the problem outlined. After first trying out other substances, he selected carbolic acid as the most suitable for his purposes. This substance had been discovered by Lemaire, in France, and already had been employed

in a desultory fashion in surgical dressings. Lister's attention to it came from the fact that it was being used extensively in the sewage fields of Carlyle, England, a short distance from Glasgow, where it had been noticed that its use was followed by a diminution of parasitic diseases among the cattle there. Lister also knew that its value in preventing the decomposition of organic materials had been demonstrated by Lemaire. Carbolic acid was available to Lister in the form of German creosote under which name it had been imported into England. After considerable study of its properties Lister decided that it was suitable for his purposes and employed it first in 1865 in the disinfection of the open wounds in compound fractures, then covering these wounds with a dressing made up with carbolic acid as a base. To Lister's immense gratification the compound fractures so treated healed without suppuration. The further development of his practice in the employment of carbolic acid belongs to the story of Lister's surgery. It should be emphasized that Lister used carbolic acid with the distinct idea of destroying the bacteria already present in a wound and of providing a dressing which would kill the organisms further deposited upon it. In other words, Lister was the first person to deliberately attempt the *disinfection* of wounds and herein his work differed radically from that of some of his predecessors, who had employed carbolic acid as a surgical dressing. Any other substance which would destroy the bacteria in wounds might have been acceptable to Lister, but it happened that carbolic acid did the work required of it and at the same time anesthetized the tissues so that its application was painless. Finally, healing of the tissues progressed favorably under the dressings. As time went on, Lister tried out a great many other disinfectants (chloride of zinc, bichloride of mercury, etc.) and later devised a new one, the double cyanide of mercury and zinc, which he believed was not inactivated by the serum and tissues.

A word or two should now be said about a much debated point. Impressed by Pasteur's work on fermentation and putrefaction, Lister regarded the atmosphere as the source of danger to open wounds, believing that bacteria were carried to them with particles of atmospheric dust. It should be noted, however, that from the very first Lister believed that bacteria might gain entrance to wounds from several other sources, chiefly from the skin of the patient, the hand of the operating surgeon, his instruments and the dressing applied. So we find him rapidly developing a technique for the disinfection of the skin, the cleansing of the hands, the sterilization of instruments and the preparation of bacteria-free dressings impregnated with substances capable of destroying micro-organisms. As was to be expected, he placed chief reliance on carbolic acid for this purpose. Later Lister's ideas changed as to the source of the bacteria which brought about putrefaction. He was eventually convinced that the bacteria of the air are harmless, calling definite attention to this at the London Medical Congress in 1881 and confirming it at the Berlin Congress in 1890. He therefore abandoned his complicated apparatus for spraying the atmosphere with carbolic acid. The main thesis that bacteria are the cause of the suppuration and putrefaction of tissues Lister never doubted, despite the opposition of many of his colleagues and despite the fact that as surgical technique improved and surgical bacteriology developed, successful results were obtained by other methods. It must be admitted that carbolic acid, used in such quantities as made necessary by Lister's original methods,

was a dangerous agent and attacks of haemoglobinurea were not uncommon in a surgeon, after a long operation in which his hands were frequently immersed in strong solutions, or after a day spent in the atmosphere of carbolic acid produced by Lister's spray. On one occasion indeed Lister was invited to examine the work of one of his colleagues who had gotten brilliant results without employing carbolic acid. His comment is interesting. He admitted that the results of the other surgeon were as good as his own but he said that while "I do not understand the matter thoroughly, I will never abandon the thesis that bacteria are the cause of putrefaction in wounds and that their entrance must be prevented."

During the course of Lister's observations on the disinfection of wounds and the perfection of his technique he controlled his work constantly with his microscope, studying his tissues and looking for micro-organisms. One might ask at this point why Lister did not attempt to bring satisfactory experimental proof of his thesis by the inoculation of animals with septic material. Koch did. As soon as Koch learned to handle bacteria and was satisfied that he could obtain them in pure culture, he took material from suppurating wounds, inoculated animals and produced infections. Koch's paper on Wundinfectionskrankheiten, published in 1878, brought final proof of the relationship of bacteria to surgical infections and is one of our great classics in bacteriology. The answer to the question I have just raised is found in Lister's own words. As he said, the daily observation, carried out over long years, that micro-organisms are always present in suppurating wounds and are not to be found in wounds healing without suppuration, was far more convincing to him than any amount of experimental work on animals. Lister did, however, carry out several procedures which in the main established his thesis experimentally. Thus he obtained blood from animals under antiseptic precautions and succeeded in keeping it free from putrefaction indefinitely. Portions of this sterile blood he now exposed to the atmosphere, noting the decomposition which followed. Bits of this septic material were now transferred to his sterile blood and characteristic putrefaction promptly ensued. Lister also produced suppuration in animals. In his attempts to devise methods for the suturing of blood vessels, he cut down on the larger arteries, tied off short segments and introduced small glass canulas containing putrefactive products. The subsequent spread of the suppuration Lister noted with care and interest.

So much for the bacteriological aspects of Lister's work on wounds from which we may draw three main conclusions. Lister was the first to establish the thesis that bacteria are the cause of suppuration and putrefaction in the animal body; the first to attempt the disinfection of infected tissues; and the first to devise methods to prevent suppuration and putrefaction by preventing the entrance of micro-organisms.

The rest of Lister's bacteriological work may be dismissed with a few words. It relates chiefly to the bacteriology of milk and he was hampered, like other men of his generation, by his inability to obtain pure cultures. He did prove that milk, as it comes from the animal, is generally free from bacteria and if protected from subsequent contamination remains clean and sweet. He further observed that all samples of milk, whether gotten at the dairy farm or at the city shops, reveal the same types of micro-organisms. In other words, milk exerts a selective action on

bacteria so that only certain kinds survive. The predominant species he obtained repeatedly and probably in pure cultures. This species he named *Bacterium lactis*. He made many attempts to devise methods to isolate single species of bacteria but those proved to be of little value after Koch discovered his poured-plate method and his solid media. Some of his experiments were highly ingenious and his results must have been beautiful to behold for he had a system of what he called "glass gardens" in which he cultivated all sorts of pigmented organisms. Apparently he never tested his disinfectants against bacteria as has been done ever since Koch worked out the procedure for this purpose. To the end of his life, Lister remained an enthusiastic bacteriologist and all of his papers show that he was thoroughly conversant with the development of this branch of science and appreciated its possible benefit to the human race.

Finally a word should be said about Lister's method of publication. Nearly all of his results, both surgical and bacteriological, are given in addresses. Some of them were delivered before scientific societies. Several in which his most important contributions are described were presented to his medical students in Glasgow, Edinburgh and London. One feels that he was an enthusiastic and meticulous teacher and gave his best to the throngs of young men who attended his clinics and followed his ward rounds. He was an advocate of clinical rather than of didactic instruction and always preferred to have his patients before him when he discussed operations or treatments. In reading his papers and studying his life one is convinced that the long opposition to his beliefs and practice shown by some of the surgeons of Great Britain, particularly by men in London, depressed him beyond measure. He evidently believed that lives were being wasted by the inability of his colleagues to see the truth as he saw it and by the refusal of some of them to come to his clinic, see his results and learn his methods. He therefore concluded possibly that it was wiser to scatter the seeds of the new truths in the fertile soil of his students and young internes rather than to cast them on the stony ground of his contemporaries. Whether this be his motive or not, it is significant that many of his followers were recruited from the crowds of young men who flocked to Edinburgh to attend his clinic and from the few who remained in his surgical service.

THE RACE FOR SWEETNESS

By Dr. J. J. WILLAMAN

THE UNIVERSITY OF MINNESOTA

ABOUT a year ago a vigorous campaign was launched in one of our corn belt states to introduce glucose as a household sugar. The glucose offered was a beautifully white, crystalline, coarsely powdered material, in appearance much like ordinary granulated sugar except with less luster. It was very pure: except for about eight per cent. of moisture it contained only 0.2 per cent. of impurities, thus comparing very favorably with its old rival, cane sugar. It was perfectly wholesome; it did not even need digesting, as did its rival; it dissolved readily, and was entirely free from any unusual or undesirable flavor. The slogan "eat corn sugar and help the farmer" was invoked, and every means was tried of inducing the people to acquire the glucose habit. The effort, however, was practically a failure. Why? Because glucose isn't sweet enough.

Most people know that the sugars are good food. Some people know how many calories there are in a piece of fudge. A few people know that sugar is not conducive to reducing. But every one knows that he or she *likes* sugar because it is sweet; and there is really no other explanation for the increase in consumption of sugar than that we are continuously craving more and more sweetness. The records show us that our consumption of sucrose (cane or beet sugar), which has been climbing steadily for decades, is still climbing, and that it has reached the really large figure of some 110 pounds *per capita*. Our sweet tooth is our strongest dental characteristic.

Little wonder, then, that glucose was disfavored because of its lower sweetness when it was used in the ordinary household ways. It mattered not that it was a quickly available sugar for the body—actually pre-digested, one might say—that eating corn sugar would help the corn farmer (although of course it would not help the beet farmer); and that it could be bought for about a dollar a hundred less than sucrose. It was conspicuously less sweet than the granulated sugar to which people had become accustomed, and they therefore got away from it just as soon as they could exercise an unhampered choice of sweetness.

THE SWEETNESS OF SUGARS

This engenders the question, how sweet is glucose and sucrose, and the rest of the sugars? Unfortunately we don't have a convenient yardstick for measuring this form of physiological response, as we measure sound by vibrations per second and color by wave-length. The best we can do is to establish a relative scale, and compare one sweet substance with another. Even this is astonishingly difficult, as can be appreciated only by trying it. Until a few years ago we had no significant figures for the relative sweetness of the sugars. Then some rather accurate measurements were made in the Home Economics Department of the University of Minnesota. From the data there developed the sugars can not only be listed in the order of their sweetness, but actual numerical values assigned, giving sucrose arbitrarily a value of 100. The values are given in the following table:

RELATIVE SWEETNESS OF CERTAIN SUGARS

Fructose	173
Invert Sugar	123
Sucrose	100
Glucose	74
Xylose	40
Maltose	32
Rhamnose	32
Galactose	32
Raffinose	23
Lactose	16

Perhaps a word would be in order as to the tasting technique in evaluating these sugars. Mrs. Cecil Stone Wahlin, a graduate student at that time, conducted the work. After trying several tasting procedures with no success, she finally decided upon the following: A series of solutions of a given sugar in distilled water was prepared, ranging in concentration from that which she was sure would be markedly sweet to every one, down to a concentration which would probably not be perceptibly sweet to any one. A subject, usually a woman, was seated, blindfolded, and given a sip of distilled water. Then the tip of her tongue was swabbed with cotton, and a drop of one of the solutions placed on the tongue. Immediately the "patient" would say, "Yes," "No" or "Doubtful," meaning that this solution did or did not taste sweet, or that she could not decide. By skipping around among the solutions, and recording the decisions, a very good idea could be obtained as to the weakest solutions of that sugar that could be tasted. And by using 15 or 20 people on each sugar the accuracy could be greatly increased. From data so obtained, the "threshold value" of each sugar was calculated. This value is the lowest concentration which is detectably sweet to 90 per cent. of the people tasting. The other 10 per cent. is designed to include the erratic, undelicate tasters, those whose judgment was perverted by having candy too near to the time of testing, and those whose nerves were dulled by too little sleep or too much movies. From the threshold values were calculated the relative ratings listed in the above table.

WHY GLUCOSE FAILED

The item in this table to be noted at this moment is the sweetness value for glucose.

This sugar, which, as has been said, was spurned for home use, is only 74 per cent. as sweet as sucrose; and, if we allow for the 8 per cent. of moisture in it, this figure is reduced to 68 per cent. It is quite plain why a cup of granulated glucose did not possess the sweetening power of a cup of the usual granulated sugar.

THE VARIOUS SUGARS

It has been implied above, and no doubt most readers are well aware, that there are several different chemical substances which belong to the class of sugars. Of course legally there is but one "sugar," and that is the product derived from the cane or beet. But since in this article we do not have to be legal, but are privileged to be accurate instead, we shall ignore legal imputations and shall call the sugars by their proper names.

The sugars are those carbohydrates which taste sweet, are soluble in water and form crystals. This will suffice for a practical definition. For comparison, some non-sugar carbohydrates might be mentioned: starch, glycogen (in the liver and muscles), cellulose (as cotton, paper, linen), dextrin (as the mucilage on postage stamps) and gums (as cherry and spruce gum). The commoner sugars can be divided into two groups, the monosaccharides and the disaccharides. The first group includes glucose, fructose and galactose, and the second, sucrose, lactose and maltose. There are, of course, several other sugars known in nature, and many others have been prepared synthetically, but these need not concern us here.

Our thesis is, then, that sweetness is the most important property of a sugar; and that when a new sugar bids for favor in the world's commerce it must either be conspicuously sweet, or it must be compensatingly cheap and abundant.

From time to time it is fitting that we take an inventory of sugars as well as of any other commodity—so as to readjust, if necessary, our viewpoint and attitude. In the case of sugars an inventory would involve a survey of the known and commoner sugars found in nature, and a consideration of them as possible commercial sugars. Such an inventory, together with a brief discussion of the occurrence and characteristics of the sugars, is attempted in the following paragraphs.

Glucose

Glucose is unquestionably the most widely distributed of the sugars. It is the sugar burned in the bodies of higher animals, and hence is the sugar that occurs normally in the blood to the extent of about 0.14 per cent. It is probably the sugar found in normal urine as a trace, and in diabetic urine in conspicuous amounts. It probably is also the sugar burned by the lower animals, and by practically all plants. We could generalize and say that it is the universal fuel sugar. This means that when other sugars are ingested in the food they are ultimately converted into glucose before burning.

Glucose, which is also called dextrose and grape sugar, occurs abundantly in fruits and some vegetables; the brown powder on the surface of some raisins and prunes consists of glucose crystals. When honey crystallizes it is glucose that separates. About a third of molasses and a fourth of sorghum is glucose.

The most important occurrence of glucose is not, however, in the form of the sugar itself, but in its compounds. For example, it combines in nature with fructose to form sucrose. It combines with itself in one way to form maltose and then starch; in another way to form cellulose. Therefore, when we reflect that sucrose is the premier commercial sugar at present, that starch is our most important source of calories, and that cellulose constitutes the structural material for all the higher plants, we can not but be impressed with the tremendous rôle that is played by glucose in our present economy.

Commercial glucose is not obtained as such from a plant or animal material. It is obtained from corn starch in this country and from potato starch in Europe, and until recently almost entirely in the form of the so-called corn sirup. The starch is separated from the hull and the germ of the corn grain in the usual manner for preparing starch, and it is then heated under pressure with a small amount of acid. A series of changes takes place that can be stated, starch→ dextrin→ maltose→ glucose. The various stages of the process overlap; hence the course of events can be stopped at such a point as will give the desired proportions of these substances. For corn sirup, it must not be allowed to go completely to glucose, since this sugar crystallizes too readily. A certain amount of dextrin is retained, which prevents this crystallization. Hence the average analysis of corn sirup shows about 25 per cent. of glucose, 12 per cent. of maltose and 37 per cent. of dextrin.

If, however, dry glucose is wanted, the reaction is forced to completion, the glucose solution is decolorized, evaporated to a thick sirup, and allowed to crystallize; and then the crystals are separated, washed, dried and bagged for market. This process has been so perfected during the last few years that the resultant glucose is pure white, as dry as cane sugar, and, as stated before, contains only 0.2 per cent. of impurities other than about 8 per cent. of moisture. It is made to the extent of thousands of tons, and sold for a lower price than is sucrose.

What is the future for this glucose? Probably no one would hazard a prediction. For many manufactured food products, for example, certain candies, cookies, fancy crackers, bakery goods

and ice cream, it has certain advantages over sucrose, because of the physical properties of its magmas, and because for some purposes lower sweetness is required. As a household sugar, and as a general sweetening agent, it carries a handicap in the race.

Glucose from Sawdust

If water be made to combine chemically with cellulose, glucose is formed. Such hydrolysis can be brought about in various ways, and the methods have been studied for many years. But this is one of the main laboratory processes which is difficult to apply commercially. A few years ago the Forest Products Laboratory at Madison, Wis., had considerable success in converting sawdust into cattle feed; but apparently there is not as yet a pinching need for sugar feeds, and the process has not advanced appreciably.

Again, the same laboratory experimented with the fermentation of the glucose formed from sawdust, with the idea of utilizing waste wood materials for power alcohol. About 30 per cent. of the sawdust could be converted to glucose, and this was readily fermentable. But this material has to compete with cheap molasses for alcohol production, and so far it has not made much headway.

At the Congress of Chemists in London last summer much discussion was leveled at three different processes for the hydrolysis of cellulose. Each of these processes claimed a yield of at least 60 per cent. of the weight of the wood as glucose, with the theoretical yield placed at 68 per cent. Such yields would be a decided advantage in the attempt to place ethyl alcohol motor fuels on the market in competition with gasoline and with synthetic methyl alcohol.

Fructose

This is the queen of sugars for sweetness. It leads sucrose in this respect farther than sucrose leads glucose. For many years it has been recognized as the sweetest sugar, without any definite value being known; and it has long been predicted that if it could only be prepared in commercial quantities it would lead the sugar world in popularity. But the great stumbling block was its obstinacy in refusing to crystallize. It could be obtained in sirup form, but as a sirup it could hardly hope to compete with dry sucrose, or with the other sirups having distinctive flavors. Therefore hope for this queen languished, until a few years ago the problem was tackled by some of the chemists in the Bureau of Standards in Washington. Under the proper conditions of persuasion the queen was induced, quite lady-like, to change her mind; and most beautiful white crystals were obtained. The crystals formed copiously, and could readily be separated from the molasses and dried.

The process is still in the experimental stage, but semi-commercial scale operations indicate that there is every chance of its succeeding ultimately. Mr. Hugh Farrell, in his recent enlarged edition of "What Price, Progress," says,

> Right off you will not get the full significance of what this means. In the first place, it means that this country is on the verge of complete independence of foreign sources of sugar supply. (It imports 8,000,000,000 pounds of sugar every year, four fifths of all it uses.) It means that science and research have found the solution of the "farm problem" for which the politicians have been blindly groping, and it also means the gradual development of a vast new industry based on sugar from corn and Jerusalem artichokes. And that may mean that this country is to become a source of supply of the 40,000,000,000 pounds of sugar the world consumes every year.
>
> The only information I have as to the cost of production of levulose (the other and the uncertain factor in the calculation) is a statement made by representatives of the Bureau of Standards to the effect that levulose can "probably be produced on a competitive basis" with the older sugars.
>
> The ramifications of this possible revolution in a great world industry extend in all directions and into all lines of human activity; they touch home investments, international banking, world shipping and agriculture.

Fructose, like glucose, occurs very widely in the plant world, especially in fruits; it constitutes half of honey, and about the same proportion of molasses and of sorghum as does glucose. None of these sources, with the possible exception of molasses, could be used for the commercial production of the sugar. Just as glucose is obtained most easily and cheaply from starch, so is fructose obtained from a starch-like substance called inulin. This is found to the extent of 12 to 15 per cent. in the tubers of the dahlia and of the girasole, or Jerusalem artichoke, and to a lesser extent in the roots of the dandelion and the chicory.

The Bureau of Standards investigations have been largely with the artichoke, and this in many ways seems to be the most promising source. It has some decided agricultural advantages. It is a vigorous plant, and is not especially particular where it grows. It produces large quantities of tubers, from 700 to 1,000 bushels per acre being an expected yield. It has practically no insect enemies or fungus pests. It is entirely a machine-cultivated crop.

And these qualities are resident in the plant as we find it now. What improvements may we expect if it is put through a process of education such as the sugar-beet received at the hands of the plant breeder and the chemist?

Molasses may prove to be another source of fructose. In the manufacture of sucrose from the cane or beet, the removal of one crop of crystals after another results in the gradual accumulation of the non-sucrose constituents, largely fructose and glucose, in higher and higher concentration. In the final molasses, which in the tropics is thrown away by the thousands of tons, there is in the aggregate a tremendous quantity of fructose which could conceivably be recovered.

When all the manufacturing wrinkles have been smoothed out, and the girasole or dahlia tubers have been improved beyond recognition, and the public has learned to use the new queen, who will say what the limit of her uses will be, or what heavenly products of ecstatic sweetness will be developed?

Galactose

This is an unattractive, little known, un-prepossessing sugar. But it is not insignificant. It has at least two claims for greatness. One is that it constitutes half of the lactose molecule, and hence is half of the carbohydrate food of the nursing animal. The other is that it is uniformly found in brain and other nervous tissue, and hence has an integral part to perform in the functioning of our body machine. In spite of this, however, the odds are decidedly against its ever becoming a commercial sugar, for the reasons that it lacks sweetness, and that, although it is a constant constituent of nerve tissue, it apparently is not a critical sugar in our diet.

This sugar occurs as galactan in many plant materials, and notably in the wood of the western larch. Galactan holds somewhat the relation to galactose that cellulose does to glucose. Several years ago it was found that by treating the sawdust of this larch with nitric acid, the galactan could be converted to mucic acid. Mucic acid has always been just a laboratory plaything. But it can replace tartaric acid in baking powder, and this fact opens up a new possibility for the commercial utilization of galactose.

Sucrose

Sucrose enjoys the distinction of being the only carbohydrate which may legally be called "sugar." When the law says "sugar," sucrose is meant. This is a relic of the days when there was no other commercial sugar; and, with its usual inertia, the law has not changed with changing conditions, in spite of the fact that many illogical and unscientific results of this definition of sugar hamper the development of the glucose industry,

A LACTOSE FACTORY

THE COW USES PASTURE GRASS AS RAW MATERIAL FOR MAKING MILK, WHICH IS THE ONLY KNOWN SOURCE OF THE SUGAR LACTOSE.

SUGAR BEETS WAITING THEIR TURN AT THE FACTORY,

WHERE THEIR SUCROSE WILL BE EXTRACTED AND CRYSTALLIZED.

THE BEES COLLECT FLOWER NECTAR,
A DILUTE SOLUTION OF SUCROSE, AND THEN CONVERT IT INTO INVERT SUGAR. THE LATTER GIVES HONEY ITS INTENSE SWEETNESS.

and will in turn also hamper the fructose industry.

In order to show the enormity of the sucrose industry let us just mention the figure of 23,000,000 tons, which is approximately the world's consumption of this sugar as granulated sugar at the present time. A great deal more is eaten in fruits and vegetables, where it occurs very extensively. Yes, indeed, it is *the* sugar of commerce, and enormous industries are built for its production and transportation and refining and distribution, in all parts of the world. And the Congress can get up an argument over a sugar tariff as quickly as it can over the building of another man-of-war. The above figures became more impressive when the extreme purity—99.8 per cent —of these millions of tons is considered. Truly, the preparation of such a pure material, on such an enormous scale, and from such unpromising materials as was the beet a century ago and the cane two centuries ago, is a real achievement of civilization.

Sucrose is too well known to warrant any detailed discussion here. Just one phase of its chemistry may be brought out, for this phase dovetails with the discussion of glucose and of fructose above. Sucrose is a disaccharide, which means that it consists of two simple sugars combined chemically. When water is forced into the sucrose molecule chemically, the latter is split; and the two constituent simple sugars are set free. Glucose and fructose are the sugars in this case; the splitting process is called inversion, for a reason which need not concern us here; and the resultant mixture of equal parts of these two sugars is called invert sugar.

The inversion of sucrose can readily be brought about by heating it with a dilute acid. Thus when fruit jellies are made, the acidity of the fruit is quite sufficient to accomplish considerable inversion. Hence the question used to come up time and again, "Should the sugar be put in at the beginning or the end of the boiling of the fruit juice?" Some authorities said at the end, for by the inversion of the sucrose sweetness is lost. Others said at the beginning, because there would be a gain in sweetness. The correct answer is found in the table of sweetness values for the different sugars. Invert sugar is rated as 123.

There is thus a gain in sweetness. Furthermore, if allowance is made for the fact that 100 pounds of sucrose becomes 105 pounds of invert sugar, because of the chemical union of water with it, the sweetness value for inverted sucrose then becomes 130. In other words the sweetness of 100 pounds of sucrose can be made equal to that of 130 pounds by inverting it. This process is practiced to a considerable extent at the present time in the confectionery, baking and ice cream industries, and it was advocated during the war as a "sugar stretching" measure.

Lactose and Maltose

These disaccharides may well receive our sympathies. They are very useful sugars, they are beautiful sugars. But in the race for sweetness they will scarcely be granted a passing glance.

There is some compensation in this dearth of sweetness in lactose, for the dietitian is enabled to boost the caloric value of a pudding very markedly without its becoming nauseatingly sweet for a patient recovering from, say, typhoid fever. As our hygiene improves, the market for lactose for this purpose will become more insignificant than ever.

Lactose is found in milk, and it is found nowhere else in the plant or animal world. It is unique in the fluid designed for nursing mammal. And it is found in milk throughout the mammalian world—from woman down to the Australian duck bill, a mammal so primitive that it still lays eggs like a reptile.

A certain amount of milk sugar is manufactured for use in modifying cow's milk for infant feeding. Some is also used in diluting drugs for stamping into pills. A large quantity of lactose goes to waste in the buttermilk, skimmilk and whey which is thrown away in the dairy industry. It is unfortunate that some further uses have not been found for this sugar, since it is rather easily prepared, and since such quantities of it are available in wasted products. Some day research will undoubtedly find a use for it.

Maltose is a rather obscure sugar. It occurs in animals not at all, and in plants only in small amounts. The only abundant occurrence of it is in malted grain, where it arises from the starch during germination. It is prepared commercially from barley malt, and sold as a sirup. Its only devotees, however, are those who try forlornly to carry themselves back to the pre-Volsteadian days

A FIELD OF GIRASOLES,

OR JERUSALEM ARTICHOKES, WHICH, BY A NEW PROCESS, WILL YIELD 4,000 POUNDS PER ACRE OF CRYSTALLINE FRUCTOSE, A SUGAR NEARLY TWICE AS SWEET AS OUR COMMON SUCROSE.

A STRICTLY MODERN INDIAN MAPLE SUGAR CAMP

MAPLE SUGAR IS IMPURE SUCROSE, AND THE IMPURITIES CONTRIBUTE THE DELECTABLE FLAVOR TO THIS OLD FORM OF SWEETNESS.

by "rolling their own." Maltose crystallizes with some difficulty, and this, coupled with its only moderate sweetness, puts it quite out of the running as a commercial sugar possibility. Since maltose can be obtained only from starch, by hydrolysis, the latter process can better be carried to the glucose stage and sweetness thus gained.

Non-sugar Sweetening Agents

There are several artificial compounds, like saccharin and dulcin, which are far sweeter than any sugar known. They are usually considered to be several hundred times as sweet as sucrose. The greatest of them all is perillaldehyde alpha-anti-aldoxime. It is about 2,000 times as sweet as sucrose, and this, I believe, justifies its long name. They will probably, however, never be allowed to run in the race. Perhaps their synthetic origin professionalizes them, for they have no nutritive value, and were pronounced by Dr. Wiley's poison squad many years ago to be actually deleterious to health when consumed habitually. Furthermore, their sweetness is not of the same quality as that of the sugars; there is a drug-like accent to it that is not wholly agreeable.

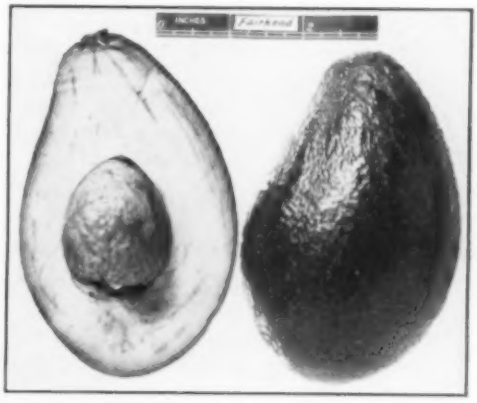
Then there are known in plants several marvellously sweet substances which are related to sugars, but which are technically glucosides. Such a one is rebaudin from Stevea, and estevin from the caa-ehe plant. The Indians gather the leaves of the latter, and dry them for sweetening purposes. Most glucosides are physiologically active, and some are used as drugs; these properties would have to be surveyed carefully before the

compound could be given further consideration for a general sweetening agent.

Future Sugar Discoveries

Since, in the above list of sweetness values, only a few sugars are indicated, and since we have summarily dismissed most of them as being of little promise, a legitimate question is, "What are the chances of other sugars being discovered which might have favorable sweetness and which might be commercially developed?"

It is safe to hazard the opinion that, in the immediate future, the chance is slight. The list of sugars given above includes most of the sugars utilizable in the human body which are known to be at all widely distributed in the plant world. (Since the animal world shows surprisingly little variety in the kinds of sugars found in it, it is hopeless to look there.) Glucose, fructose and sucrose are the best in the list, and any competing stranger would have to be superior at least to glucose in sweetness, and to sucrose in abundance and in ease of preparation.



THE AVOCADO,
OR ALLIGATOR PEAR, IN WHICH HAS BEEN FOUND A VERY UNUSUAL SUGAR, THE SWEETNESS OF WHICH IS NOT AS YET KNOWN.

A BUSHEL OF CORN
THIS BUSHEL OF CORN CAN BE CONVERTED INTO ABOUT 25 POUNDS OF STARCH, OR 28 POUNDS OF GLUCOSE, OR 2 GALLONS OF ALCOHOL, BESIDES 5 POUNDS OF MOLASSES, 1 POUND OF OIL AND 27 POUNDS OF "GLUTEN" FEED.

New sugars are discovered at intervals. In 1916 a very unusual sugar containing seven carbon atoms—all ordinary sugars contain five, six or twelve carbons—was found in the avocado by investigators of the Bureau of Chemistry. If it proves to have worthy sweetness (its sweetness has not been measured); if it proves to be readily obtainable from the avocado; if it is found possible to produce a variety of the pear with a 15 per cent. concentration of this sugar; if horticulture can reduce the cost of this fruit from about 25 cents each to $10 a ton—in short, if enough of these "ifs" are satisfied, mannokeptoheptose may qualify for the race.

Again in 1917 another seven-carbon sugar was discovered in the stone-crop,

Sedum spectabile. It was named sedoheptose. Whether it can be seriously considered as a commercial sugar will depend almost altogether on the answer to the above four questions. The answers to none of them are now known.

In 1924 a still stranger sugar was found in yeast. This sugar contains sulfur. This is an extraordinary thing; it is unheard of among sugars to contain sulfur in the molecule; it simply isn't done by these aristocrats. But the ethics of the situation will never concern us, for there isn't a ghost of a chance of this thio-sugar even being considered commercially. It occurs in the minutest amounts of yeast; long and exacting labor is required even to prepare a doll's thimbleful of it; and we should have to use some kind of sugar to feed the yeast to make the new sugar.

Then, in 1923, some British biochemists isolated from cabbage a queer little three-carbon sugar, which is so queer that possibly it isn't a sugar at all. It would have been more in keeping with our expected order of things if the sulfur-sugar had been found in the cabbage. But such are the facts. The little three-carbon sugar—nameless, so far—is handicapped, like the other, in the inconsequential amounts in which it occurs. Of course cabbage has many agricultural advantages, if that were the prime consideration.

These examples of sugar discoveries are given partly to corroborate the statement that such discoveries are made from time to time, and partly to show that nevertheless such discoveries are mostly of unusual, even fantastic types of sugars, quite different from the ones which are at present well known. However, hosts and hosts of plants have not had their sugars identified and assayed. There is unlimited opportunity for research in this field. And foolish is he who would minimize or scoff at the chances of some sugar, unknown in 1927, looming large in the world of sweetness in 1950 or in 2000. And when each new discovery is made, the present writer is convinced that the first criterion to be applied will be that of sweetness. If this be unfavorable, the sugar will have to possess some unusual physiological value, such as utilization by diabetics, before it will be given further consideration.

THE PROGRESS OF SCIENCE

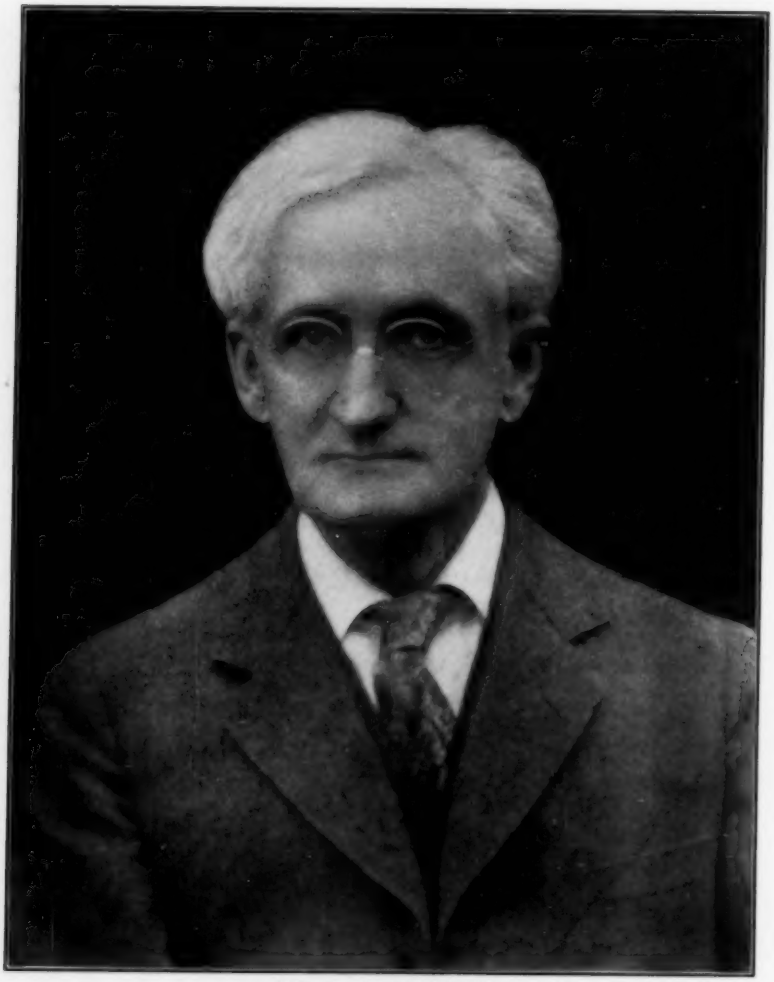
THE NASHVILLE MEETING OF THE AMERICAN ASSOCIATION

After an interval of fifty years the American Association for the Advancement of Science returns to Nashville for its eighty-fourth meeting. It has met in only three other southern cities. In 1850, two years after its foundation, the meeting was in Charleston, then a relatively more important scientific center than it is to-day. Joseph Henry, one of the world's great leaders in physics, was president, and as his successor was elected Alexander Dallas Bache, great-grandson of Benjamin Franklin, who did notable work, especially as superintendent of the Coast Survey. Bache was succeeded by Louis Agassiz, and there then followed Benjamin Peirce, James B. Dana and John Torrey, men eminent respectively in zoology, mathematics, geology and botany. There were at that time 622 members of the association, now there are over 14,000, more than twenty times as many, but it could not provide twenty men a year as distinguished as those who have been named.

Simon Newcomb, the astronomer, was president at the time of the last Nashville meeting, and Othniel C. Marsh, the paleontologist, was elected to succeed him. Here again we have men distinguished outside the limits of their science and their country. The other two meet-

COLLEGE HALL OF THE UNIVERSITY OF NASHVILLE

HOUSING THE ADMINISTRATIVE OFFICES AND LIBRARY, ALSO THE LABORATORIES OF PHYSICS, ENGINEERING AND GEOLOGY.



DR. L. H. BAILEY
RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION.

ings held in the south were at New Orleans in 1904 and at Atlanta in 1913. At the former meeting the three presidents—the retiring president, who gives his annual address, the one who presides and the one who is elected—were W. G. Farlow, Harvard botanist; C. M. Woodward, St. Louis engineer, and W. H. Welch, Johns Hopkins pathologist. At Atlanta the three were E. C. Pickering, Harvard astronomer; E. B. Wilson, Columbia biologist, and Charles W. Eliot.

Fortunately the American Association is able to continue its distinguished line of succession in the presidential office. At the opening session at Nashville the address of the retiring president will be given by Dr. L. H. Bailey, distinguished as a systematic botanist, author and editor of our most valuable books on cultivated plants and rural life. Professor Arthur A. Noyes, who presides at Nashville and will make the address at the New York meeting a year hence, was for many years associated with the Massa-

DR. ARTHUR A. NOYES
PRESIDENT OF THE AMERICAN ASSOCIATION.

chusetts Institute of Technology. In 1920 he joined Dr. W. H. Hale and Dr. R. A. Millikan in the noteworthy development of the California Institute of Technology at Pasadena, where he is director of the Gates Chemical Laboratory. Recognition of Dr. Noyes's research has just now been made by the award to him of the Davy medal of the Royal Society.

Those members of the association who attended the meetings at New Orleans and Atlanta remember them with special pleasure, for they gave insight into our broad and varied civilization. Nashville may seem remote to the provincial east, which indeed is one of its attractions, but it is not far south of the center of population of the United States. The city has long been one of the chief educational centers of the south and has enjoyed a notable development in recent years. Vanderbilt University, endowed by Cornelius Vanderbilt in 1873, now has in addition to other departments a medical school of high standing, to which the General Education Board has given

$5,500,000 and the Carnegie Foundation $1,500,000. The George Peabody College for Teachers has a national reputation, as has also Fisk University for the education of Negroes.

Edward Emerson Barnard, the eminent astronomer, was born in Nashville in 1857 and was graduated from Vanderbilt University. He made many valuable contributions to astronomy, among which may be mentioned the discovery of the fifth satellite of Jupiter. It is specially fitting that a general session at this Nashville meeting should be devoted to his memory. The address will be made by Dr. Robert G. Aitken, associate director of the Lick Observatory, retiring vice-president for the section of astronomy.

Among other general sessions is the fifth annual Josiah Willard Gibbs lecture, to be given by Professor Ernest W. Brown, of Yale University, whose subject is "Resonance in the solar system." The sixth annual Sigma Xi lecture will be by Dr. Clarence C. Little, president of the University of Michigan, who will speak on "Opportunities for research in mammalian genetics."

An evening lecture is to be devoted to a lecture on "Science and the Newspapers," by Dr. William E. Ritter, the distinguished zoologist, who has been a leader in the organization of Science Service, endowed by the late E. W. Scripps for the purpose of supplying science news to the daily press. This general session will continue and round out an all-day symposium on "Science for the People," arranged by Austin H. Clark. A general session is to be devoted to a series of papers on phases of the economic relations of science workers. This program has been arranged by the committee of one hundred on scientific research, of which Dr. Rodney H. True is secretary.

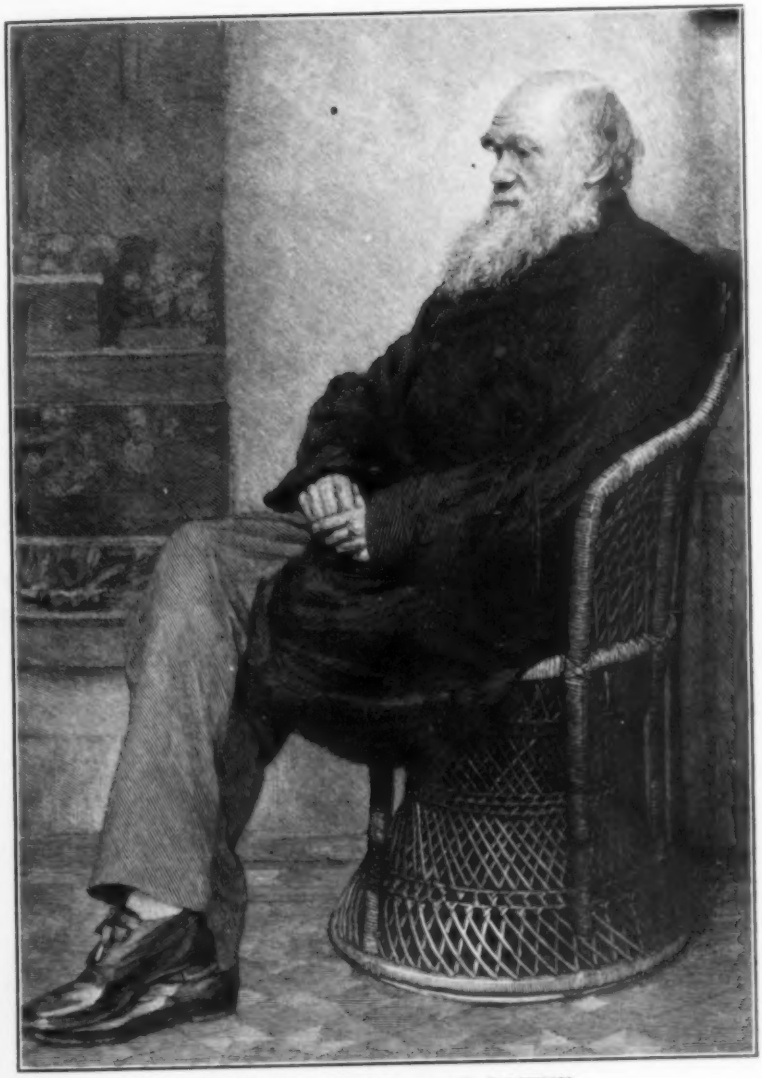
There will be popular lectures and many addresses and meetings of general interest. In addition to the sections of the association twenty-five associated societies meet with it at Nashville and there will be presented hundreds of papers, each contributing to the advancement of science.

DARWIN'S HOUSE AT DOWNE

At the recent Leeds meeting of the British Association the president, Sir Arthur Keith, announced that the council of the association was considering the possibility of purchasing for the nation the home in Kent where Charles Darwin lived for forty years. A few hours thereafter Mr. George Baxter, a retired London surgeon, telegraphed an offer to provide for the purchase of the place and for establishing a fund for its up-keep. It is understood that the donor has expressed a wish that Downe House, without and within, should be restored so far as possible to its condition in 1882 when Darwin died.

The place has remained in the possession of Professor Francis Darwin, the distinguished botanist, son and biographer of Darwin, but is now leased for a girls' boarding school. The house has not been altered radically since Darwin lived there, but the furniture has been removed and the paneling covered for its protection. A corrugated iron garage and a laundry with a concrete tennis court have been built, and it is said that the grounds and orchard have been somewhat neglected.

There have been various proposals to purchase the house at Downe (it was formerly spelled Down) since Darwin's death. At one time Adam Sidgwick and Francis Darwin were among those who proposed to secure the house for the Royal Society and use it as a biological station for the study of heredity. It is said that Andrew Carnegie offered to



DARWIN AT HOME AT DOWNE

DOWNE HOUSE FROM THE GARDEN

THE ILLUSTRATIONS ARE FROM THE "LIFE AND LETTERS," THOSE OF THE HOUSE HAVING BEEN ORIGINALLY PUBLISHED IN THE CENTURY MAGAZINE.

purchase the house and provide a sum of money to settle once for all the controversy over evolution.

Darwin returned to England from the voyage on the *Beagle* in 1836, and lived in Cambridge and in London until his marriage in 1839 and for three years thereafter. He tells us that during this period he did less scientific work than during any other period in his life. He decided in the interest of his health and work to live in the country and, after several fruitless searches in Surrey and elsewhere, found the house at Downe and purchased it.

The village of Downe, though only sixteen miles from London, was remote, reached only by a coach drive of some twenty miles. The nearest railway station was ten miles distant, and at first Darwin used to take this drive with an old gardener as his coachman, who drove with great slowness and caution up and down the many hills. A little later,

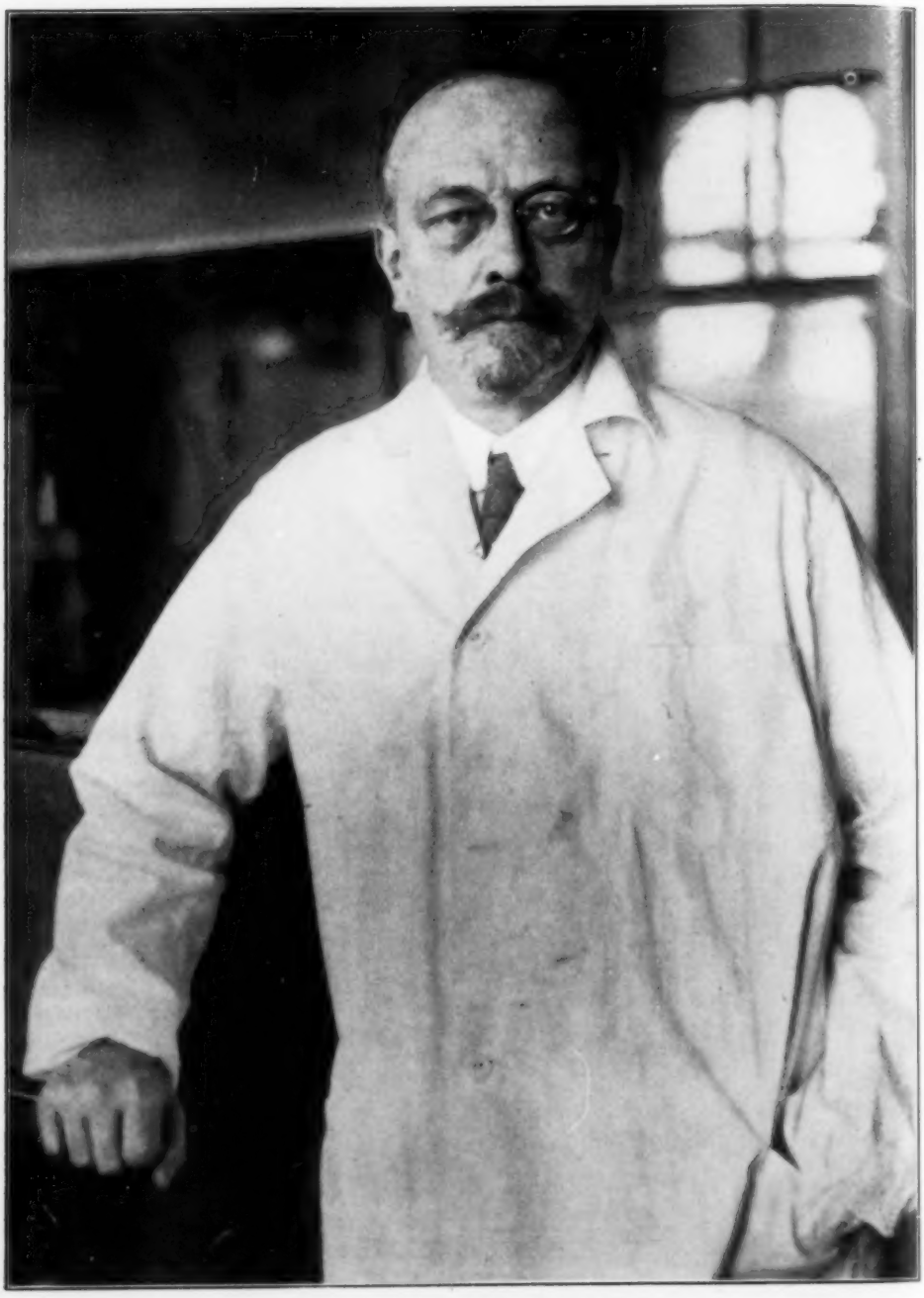
THE STUDY IN DOWNE HOUSE

owing to his health, he ceased to attend scientific meetings in London. Though railways are now closer, Downe is still out of the world, being three miles from the nearest station.

As Sir Francis Darwin tells us in the "Life and Letters," the village stands on a solitary upland country, five to six hundred feet above the sea. The country has little natural beauty, but possesses a certain charm in the strips of wood capping the chalky banks and looking down on the ploughed lands of the valleys. The village has three or four hundred inhabitants with a little flint-built church.

The house stands one quarter of a mile from the village and is close to the road. When purchased by Darwin it was a square brick building of three stories, covered with shabby whitewash. The ground was open, bleak and desolate. After its purchase the house was covered with stucco and enlarged on several occasions. The grounds were planted and from the eighteen acres of land that were bought with the house a shrubbery was cut off, which ultimately became an experimental plot where greenhouses were put up. Darwin himself in a letter to Mr. Fox, written in 1843, gives his early impressions of Downe as follows:

We are now exceedingly busy with the first brick laid down yesterday to an addition to our house; with this, with almost making a new kitchen garden and sundry other projected schemes, my days are very full. I find all this very bad for geology, but I am very slowly progressing with a volume, or rather pamphlet, on the volcanic islands which we visited; I manage only a couple of hours per day and that not very regularly. It is uphill work writing books, which cost money in publishing, and which are not read even by geologists. I forget whether I ever described this place; it is a good, very ugly house with 18 acres, situated on a chalk flat, 560 miles above sea. There are peeps of far distant country and the scenery is moderately pretty: its chief merit is its extreme rurality. I think I was never in a more perfectly quiet country. Three miles south of us the great chalk escarpment quite cuts us off from the low country of Kent, and between us and the escarpment there is not a village or gentleman's house, but only great woods and arable fields (the latter in sadly preponderant numbers), so that we are absolutely at the extreme verge of the world. The whole country is intersected by foot-paths; but the surface over the chalk is clayey and sticky, which is the worst feature in our purchase. The dingles and banks often remind me of Cambridgeshire and walks with you to Cherry Hinton, and other places, though the general aspect of the country is very different.



PROFESSOR JOHANNES FIBIGER

PROFESSOR FIBIGER'S WORK ON THE EXPERIMENTAL PRODUCTION OF CANCER

PROFESSOR JOHANNES FIBIGER, director of the Pathological Institute of the University of Copenhagen, has been awarded a Nobel prize for physiology and medicine. Although his investigations were begun in 1907, the initial difficulties were so great that his first account did not appear until 1912. The interval was devoted to a piece of detective work as brilliant as any to be found in fiction, the only counterpart of which, in modern medicine, is the apprehension of "Typhoid Mary" by Soper.

In the year 1907, then, Fibiger was engaged in the study of tuberculosis, and in the course of his work had occasion to autopsy three wild rats. In the mucous membrane lining the prostomach of each he found an intense thickening of the epithelium, which at certain points had progressed to the formation of warty outgrowths. The process appeared to be a fibro-epithelial tumor, possibly of malignant character; its cause, a parasitic worm belonging to the Nematode group.

A lesion of the stomach such as this had not been previously described in rats, nor was the accompanying worm familiar to zoologists. In order to learn something of the nature and occurrence of this unknown disorder, Fibiger examined the stomachs of 1,144 rats from various sources, but found neither the Nematode nor the disease which he was seeking, and he was unable to transfer the latter to other rats by inoculating or feeding the affected tissue. For the average man this would have sufficed; but those who win a Nobel prize are not average men.

Attempts to transmit the disease by feeding experiments having failed, Fibiger began to consider the possibility that his parasite was not directly transferable from rat to rat, but required the intervention of another host. Now it had long been known that a cockroach (*Periplaneta orientalis*) is the intermediate host for a similar worm, also an inhabitant of the rat's stomach, and Fibiger therefore examined wild rats from a locality in Copenhagen that was swarming with this pest, but found neither Nematode nor hyperplasia. Transmission experiments, also, were disappointing, for rats fed with the roach remained in good health.

A more encouraging result attended the search in rats from a large sugar refinery, where a different cockroach (*Periplaneta americana*) ruled. Within about nine months, sixty-one rats were caught in this building, and in forty of them the long-sought Nematode was found, while in no less than eighteen of these forty the strange hyperplastic disease was a concomitant feature of the infestation. Rats fed with the *americana*, too, developed the characteristic changes in the stomach, and in some the disease had actually progressed to the inception of cancer. There could no longer be any doubt that the disease depended upon the presence of the parasite or that *Periplaneta americana* was the intermediate host; indeed, the larval stage of the worm was easily demonstrable in the muscles of the insect.

The experimental production of cancer had at last been achieved. That is the great and enduring value of Fibiger's work, the major part of which has now been told, and it remained only to consolidate and amplify his basic observations. There followed in due course a technical description of the parasite, for which the name *Spiroptera neoplastica* was chosen, and an account of investigations in which problems were attacked that had never before been susceptible of experimental approach. It was now possible to discover the period required for the inception of cancer,

which was found to be at least six weeks, and to inquire into the importance of age. Rather unexpectedly, age turned out to be a less decisive factor than clinical experience had suggested, for rats weighing but thirty grams at infestation proved readily susceptible. Hence it appeared that the length of time over which the irritant had acted was more important than age in the etiology of carcinoma.

The manner in which the parasite produces the cancer is still a mystery. True enough, inflammation was an almost constant feature in infested stomachs, but no relation was discoverable between the degree of inflammation and the development of cancer, an observation which has since been substantiated in other types of experimental new growth. The active agent seemed to be some sort of poisonous secretion of a nature entirely unrecognized, rather than a specific cancer virus.

Had this work been accomplished ten years before it was, there is no doubt that it would have been more loudly acclaimed. But not only did the war withdraw all interest from cancer research; in the meantime there had been discovered, in Japan and in America, two other ways of inciting malignant tumors, one of them much less laborious than Fibiger's. His method, accordingly, instead of standing unique, as it well might have done for a time at least, became only one of three means to the desired end. But this does not lessen the value of his work, which will remain an enviable model of shrewd observation and patient experiment.

W. H. W.